A Brief History of CD/DVD

The first disc that could be written and read by optical means (using light as a medium) was developed by James T. Russell. In the late 1960s, Russell created a system that recorded, stored, and played audio/video data using light rather than the traditional contact methods, which could easily damage the disks during playback. Russell developed a photosensitive disc that stored data as 1 micron-wide dots of light and dark. The dots were read by a laser, converted to an electrical signal, and then to audio or visual display for playback.

Russell's own company manufactured the first disc player in 1980, although the technology never reached the marketplace until Philips and Sony developed the technology. In late 1982, Philips and Sony released the first of the compact disc (CD) formats, which they then called CD-DA (digital audio). In the years since, format has followed format as the original companies and other industry members developed more adaptations of the original specifications.

Digital Versatile disc (DVD) had its beginning in 1994, when two formats, Super disc (SD) and Multimedia CD (MMCD) were introduced. Promoters of the competing technologies failed to reach an agreement on a single standard until 1996, when DVD was selected as a convergence format. DVD has, in the few years since, grown to include variations that do anything that CD does, and more efficiently. Standardization and compatibility issues aside, DVD is well-placed to supplant CD.

Magnetic vs Optical Media

Optical media are storage media that hold information in digital form and that are written and read by a laser; these media include all the various CD and DVD variations, as well as optical jukeboxes and autochangers. Optical media have a number of advantages over magnetic media such as the floppy disk. Optical disc capacity ranges up to 6 gigabytes; that's 6 billion bytes compared to the 1.44 megabytes (MgB) - 1,440,000 bytes - of the floppy. One optical disc holds about the equivalent of 500 floppies worth of data. Durability is another feature of optical media; they last up to seven times as long as traditional storage media.

The Optical Storage Technology Association (OSTA) is an international trade organization dedicated to the promotion of standardized writable optical technologies and related products. Incorporated in 1992, OSTA is made up of members and associates from the leading optical media manufacturers and resellers of North America, Europe, and Asia. OSTA members include Adaptec, Hewlett-Packard, Philips, and Sony.

Hard disks, floppy disks and DAT (digital audio tape) are types of magnetic storage media. Magnetic media function similarly to an audio cassette tape player: there is a device called a *read/write head* , which creates and reads magnetic impressions on the disk. These microscopic magnets can be polarized to represent either a zero or a one, which is stored as binary data, the only type of data that computers can deal with.

CDs and DVDs are types of optical storage media. Optical storage media are written and read with an extremely fine, precisely aimed laser beam. Data storage consists of millions of indentations burnt into a reflective metallic surface. The indentations refract (change the direction of) the light, reducing the intensity of the reflection. When a laser beam is aimed at the disc surface through a two-way mirror, sensors register the difference in reflection intensity as binary data - zeros and ones. The two main advantages of optical storage media are greater data density and increased stability. Data can be more densely packed on optical media than on magnetic media. Also, the life span of optical media is much greater than that of magnetic media. After about 5 years, the magnetic impression storing data on magnetic media fades away.

Optical Media Drives

Drives (such as the hard drive, floppy drive, CD-ROM, CD-R, CD-RW, and DVD-ROM drives) are the hardware devices that read computer data from disks. After the hardware is installed, the operating system will assign a drive letter. Typically, on a DOS or Windows-based personal computer, the letters "A," and "B" are reserved for the floppy drive (years ago one of the drives was used for a different type of removable disk, larger than the floppy), the letter "C" is reserved for the hard drive and the letter "D" is usually reserved for the CD-ROM. Drives added subsequently are generally assigned the first available letter after existing drives.

Data can be read once the disc spins (for one to two seconds) and the operating system has located and identified the drive. The CD-ROM's own file system is standardized in ISO 9660.

Optical Media Drive Capabilities

Drive Type	"Read" & "Write" Capability
CD (CD player)	Reads audio CD only
CD-ROM (Compact Disk-Read Only Memory)	Reads audio CD, CD-ROM, CD-R, Photo CD
CD-ROM multiread (Compact Disk-Read Only Memory, Multiread)	CD-ROM, CD-R, CD-RW, CD-i, Photo CD
CD-R (Compact Disk-Recordable)	Reads CD-ROM and CD-R, some read CD-RW (Writes once on

	CD-R disks)
CD-RW (Compact disc Rewritable)	Reads CD-ROM, CD-R, and CD-RW (Writes and rewrites on CD-RW disks)
DVD-RAM (Digital Versatile disc - Random-Access-Memory)	Reads all CD formats. Reads DVD ROM. Reads and writes DVD disks.

Rotation Speed and Data Transfer Rates

Rotation speed indicates the revolutions per minute or RPM range that the drive can produce. Data transfer rate refers to the speed at which data can be read from a optical media drive.

Optical Media Drive Speed	Maximum Data Transfer Rate	RPMs (revolutions per minute)
1X CD-ROM	150 KB/sec	200 - 530
2X CD-ROM	300 KB/sec	400 1060
4X CD-ROM	600 KB/sec	800 2120
8X 12X CD-ROM	1.2 MB/sec	1600 4240
24X 50X	1.8 - 6 MB/sec	2400 6360 approximately
1X DVD-ROM	1.25 MB/sec	No exact data, but much slower than 1X CD-ROM

There are only minor increases in speed as one moves from the 24X, 32X, and 40X drives. The high rotation speeds produced can create noise and vibrations, and performance may vary from drive to drive. It seems unlikely, because of these vibrations and performance variations, that speeds will increase much above present levels. Even though a hard drive can reach much faster speeds of rotation, its enclosure stabilizes the entire mechanism and therefore avoids much of the noise and vibration inherent in the open CD-ROM drive.

Multi-beam CD-ROM Drives

A new technological development, the multi-beam CD-ROM drive uses 7 laser beams instead of one to to produce 36X performance from a 6X rotation speed. Six beams are used for reading data; the other one is used for error correction. A new development by Hi-Val in multi-beam CD-ROM drives, the first 40X drive, utilize 7 laser beams, reading simultaneously. (6 that read, and one for error correction, the same as above). The yield is true 40X performance and a transfer rate that can reach 6MB/second. The CD-ROM disc rotates as smoothly as a 6X drive.

DVD-ROM Drives

On the surface, there isn't much that would distinguish a DVD-ROM drive from a CD-ROM drive; internally, there are more similarities than differences. Drive interfaces are either ATAPI or SCSI and transport of data occurs similarly to the CD-ROM. The DVDs data layer is in the middle of the disc thickness, in order to accomodate double-sided disks, whereas data is recorded near the surface of the CD-ROM disk. The laser on the DVD drive has a pair of lenses on a swivel: one to focus the beam on the correct DVD data layer, and one for reading CD-ROM disks.

Although DVD-ROM drives have a much lower RPM (revolutions per minute) value, data transfer rates are substantially higher than a CD-ROMdrive at equivalent RPMs, because the data is compressed by the use of a greater number of smaller data pits and a smaller track pitch (the distance between tracks). For example, a 1X DVD-ROM drive transfers data at 1,250KBps, whereas a 1X CD-ROM drive transfers data at only 150KBps. By 1998, multispeed DVD-ROM drives became available that were capable of reading DVD media at double-speed, resulting in a transfer rate of 2,700 KBps, and of rotating CDs at 24X. By the end of that year DVD drive speeds had increased to 5X. Presently, DVD drives are capable of a 6X speed (8,100 KBps) for DVD media and 32X speed for reading CD-ROMs.

Optical Media Drive Interfaces

The word *interface* , defined as *the surface that connects two areas which share a common boundary* , is used to refer to the connections between certain kinds of computer hardware. For the computer to communicate with the CD-ROM, an additional piece of hardware is necessary to serve as the interface between the two devices.

SCSI (Small Computer System Interface) vs IDE (Integrated Drive Electronics)

Before you select the drive *or* interface, consider what types of connections are already present in your system. If there is an extra IDE connector on your motherboard, consider an ATAPI drive. If you have a SCSI adapter installed for your hard drive or other external devices, like scanners or drives for high-volume storage disks, or if you have a sound card that offers a SCSI interface, consider a SCSI drive.

ATAPI CD-ROM Interface

ATAPI stands for AT Attachment Packet Interface. This interface was introduced by Western Digital in 1994 as part of the Enhanced IDE specification. Initially used in hard drives, the technology is now being used in CD-ROMs as well. An ATAPI drive plugs directly into an IDE connector in your system. Unlike the SCSI or proprietary interfaces, it does not require a separate card. However, if your motherboard is jammed, many ATAPI drives come with a separate card to be used as the interface. ATAPI cards are also available as stand-alone items. The ATAPI drive and its interface are extremely easy to install and configure, are faster than most proprietary drives, and are almost as fast asmost SCSI drives.

Proprietary Interfaces

Proprietary interfaces are specific to one manufacturer and utilize that company's private standard. For example, Mitsumi, Panasonic, and Sony are three companies that manufacture proprietary CD-ROM drives and interfaces. The primary advantage of purchasing proprietary drives and interfaces is cost savings. The prices of such drives and interfaces are dramatically lower than other ATAPI or SCSI devices. The disadvantage is that the CD-ROM drive is only compatible with an interface card manufactured by the same company that produced the drive. If any other card is used, the drive will simply not function.

SCSI CD-ROM Interface

SCSI CD-ROM drives have become extremely popular, and are widely used today, especially on 4X and 6X CD-ROMs. They are both the fastest and most expensive CD-ROM drives and interface cards on the market. A SCSI CD-ROM drive is ideal if you already have a SCSI hard-drive. The drive can be connected directly to the same interface device that your hard-drive uses. If you do not have a SCSI hard-drive, a separate interface card can be installed. It can be purchased separately or may come with the SCSI CD-ROM. All SCSI devices are compatible. In addition, SCSI interfaces are extremely efficient. You can *daisy-chain* (link sequentially) up to 7 SCSI devices, both internal and external, to one interface card. For example, a printer can be connected to a scanner that is connected to an external storage device that is connected to the SCSI hard-drive that is plugged into the SCSI interface card.

Compact disc (CD)

A CD (Compact Disk) is an optical media storage device, originally developed by Philips and Sony and introduced as *CD-Digital Audio* (CD-DA) in 1982. CD-DA was originally developed to contain only audio information, digitized at a sample rate of 44,100 samples per second, in a range of 65,536 possible values (16 bits), with a storage capacity of about 650 megabytes (MB).

The specifications for CD-DA were laid out by the two companies in their 1980 standard document, informally known as the Red Book. Subsequent CD formats (as well as DVD formats) all follow the basic Red Book specification. Adaptations of CD technology have been explicated in amendments to the Red Book, including the Yellow Book (which, in conjunction with other standards, details the specifications for CD-ROM and CD-ROM XA), the Orange Book (which details the specifications for CD-R, CD-WO, CD-RW, and CD-MO), the White Book (which details the specifications for various multimedia disks, such as Video CD), the Green Book (which details the specifications for CD-I), the Blue Book (which details the specifications for Enhanced CD), the Scarlet Book (which details the specifications for Super Audio CD), and the Purple Book (which specifies the Double Density CD (DDCD).

CD Structure

According to Red Book specifications, a standard CD is 120 mm (4.75 inches) in diameter and 1.2 mm (0.05 inches) thick and is composed of a polycarbonate plastic substrate (underlayer - this is the main body of the disk), one or more thin reflective metal (usually aluminum) layers, and a lacquer coating. CDs are divided into a *lead-in* area, which contains the table of contents (TOC), a *program* area, which contains the audio data, and a *lead-out* area, which contains no data. An audio CD can hold up to 74 minutes of recorded sound, and up to 99 separate tracks. Data on a CD-DA is organized into sectors (the smallest possible separately addressable block) of information and the sectors are further broken down into logical blocks (smaller segments within a sector that can only be accessed by the logical block number (LBN) and are identified by the header bytes that hold this address information. There are a variety of logical block sizes, 512, 1024 and 2048, that might be used on different CDs, but the logical block size cannot exceed the sector size). The audio information is stored in frames of 1/75 second length. 44,100 16-bit samples per second are stored, and there are two channels (left and right). This gives a sector size of 2,352 bytes per frame, which is the total size of a physical block on a CD.

CD Mastering

In a process known as *mastering* , information from a digital tape master is used to modulate a laser beam, which is tracing a spiral track on a spinning glass disc coated with a photosensitive material. An electromagnetic current is used to vary the intensity of the laser beam and the photosensitive coating dissolves where the laser hits, creating pits in the glass. The glass disc is called a *glass master* and is in turn used to create *metal masters* (sometimes called *fathers*), formed by coating the glass master with a thin layer of nickel. For mass production, disks called *mothers* are created from the metal masters; the mothers serve as the masters for a number of metal *stampers* (sometimes called *sons*). The stampers are the forms used to mould the CD's polycarbonate layer, which is then coated with aluminum and the final acrylic layer. The process of recording a CD in a desktop environment is sometimes also referred to as mastering.

CD Recording and Playback

Data is encoded in the CD's polycarbonate layer in a continuous spiral track, from the inside to the outside, about 1.6 to 2.2 microns wide (a micron is 1/1000 of a millimeter), with pits about 0.6 microns wide scored into the track. The thin metallic layer conforms to the contours of the substrate, and the outer acrylic layer over it is impressed with the CD label.

When a CD is placed in a CD player, the recorded track is scanned by a low-intensity infrared laser. To enable a consistent scanning rate (from the smaller center to the larger outside of the disk), the rotation rate slows from 500 to 200 rpm (revolutions per minute) as the laser beam spirals outward. Two additional lasers are sometimes used to help control the focus of the primary laser and the rotation of the disk. The pits and smooth areas (the smooth areas are called *lands*) are read by a laser when the disc is played. Pits and lands reflect the light from the laser differently, and that difference is encoded as binary data: the light hitting a land reflects back directly to a photodiode, which generates an electrical pulse, while the light hitting a pit is refracted (deflected from a straight path, or scattered), and, consequently, reduced below the level needed to activate the photodiode. Based on its length, each pit is interpreted as a sequence of zeroes, and, based on its length, each land is interpreted as a sequence of ones. Digital-to-analog conversion translates the binary data into audio signals for reproduction.

UDF (Universal Disc Format)

The UDF (Universal Disc Format) resolves the numerous incompatibility problems which plagued the CD. Presented by the Optical Storage Technology Association (OSTA), the UDF file structure ensures the accessability of any file by any drive, computer, or consumer video disc player. Because of the use of disks for data, video, audio or a combination of all three, the development of a universal standard became crucial. Reasonable communication with standard operating systems became possible, it was written to be compatible with the ISO 9660 CD standard for file names and structures.

Prior to the release of Windows 98 by Microsoft, UDF wasn't supported by Windows, however, and DVD manufacturers were forced use an interim format called UDF Bridge. Windows 95 OSR2 (OEM Service Release: a version of Windows 95 incorporating bug fixes and new functionality released to PC vendors for bundling with new PCs. Not available as an upgrade to older versions of Windows95.), supports UDF Bridge. Earlier versions do not. DVD manufacturers who wanted to be compatible with Windows 95 were forced to supply UDF

Bridge support in conjunction with their hardware.

Standards and Specifications

According to industry legend, at least the original CD specification (the Red Book) was released in a booklet with a red cover. Although each of the specifications have formal titles, they are generally referred to as different colours of books.

Specification Document	Contents of Specification Document
Red Book	The Red Book, written by Philips and Sony in 1982, contains standards for the original compact disc (CD). It includes the physical characteristics of the CD and CD-DA The Red Book standard defines the format in which an audio CD must be recorded so that it will play correctly on a CD player. Red Book is the basis for all later CD standards and specification documents.
Yellow Book	The Yellow Book is the informal name for Philips and Sony's ECMA-130 standard specification for CD-ROM (Compact Disk, read-only-memory). Published by the two companies in 1988, the Yellow Book is an extension of the Red Book that enables the CD to contain data other than the audio data. In 1989, the Yellow Book was issued by the International Organization for Standardization (ISO) as*ISO/IEC 10149, Data Interchange on Read-Only 120mm Optical disks (CD-ROM)* . Because the Yellow Book only defines the physical arrangement of the data on the disk, other standards are used in conjunction with it to define directory and file structures. They include ISO-9660, HFS (Hierarchal File System, for Macintosh computers), and Hybrid HFS-ISO.

	In addition to the disc specification, optical stylus parameters, the control/display system, and sector structure, the Yellow Book includes modulation and error correction data. Definitions include two data modes, mode 1 and mode 2. CD-ROM, Mode 1 is the standard data storage mode used by almost all standard data CDs (CD-ROMs). Of the 2,352 bytes of data in each block, 2048 are allocated for the data that the user sees. The remaining 304 bytes are used for added error detection and correction code. CD-ROM, Mode 2 can contain 2336 bytes of user data. It is the same as Mode 1, except that the error detection and code correction bytes are not included. The Mode 2 format offers a flexible method for storing graphics and video. It allows different kinds of data to be mixed together, and became the basis for another standard known as CD-ROM XA (Extended Architecture). The specification for CD-ROM XA was published as an extension to the Yellow Book in 1991.
Orange Book	Orange Book is the informal name for Philips and Sony's *Recordable CD Standard* . Published in 1990, the Orange Book is a follow-up to their Red Book CD-DA (Compact disc - Digital Audio) specifications. The Orange Book is divided into two sections: Part I deals with magneto-optical (MO) drives, and Part II deals with the first recordable CD format CD-R (Compact disc - Recordable). Part III, released separately, detailed CD-RW (Compact disc - Rewritable). In addition to disc specifications for the above CD forms, the Orange Book

includes information on data organization, multisession and hybrid disks, pre-groove modulation (for motor control during writing), and recommendations for measurement of reflectivity, environment, and light speed.

Orange Book specifications enabled the first desktop disc writing. Formerly, CDs had been read-only music (CD-DA), to be played in CD players, and multimedia (CD-ROM), to be played in computers; after the Orange Book, any user with a CD Recorder drive could create their own CDs from their desktop computers.

Magneto-Optical (CD-MO) technology allows tracks to be erased and rewritten on 12cm CDs that are rated to allow millions of rewrites. These drives use two heads (one to write and the other to erase), in a double-pass process. System information may be permanently written in a small, premastered area, but the rest of the area is available for recording, and re-recording many times.

CD-R products can be written to only once, similarly to WORM (write once, read many) products. A CD-R drive records on CDs that have special recording layers and pregrooved tracks. The first tracks are a program calibration area, which is followed by the Lead-in area (where the table of contents will be written), and the program area (where the user actually records), and a Lead-out area. There are hybrid disks that include read-only and recordable areas.

Rewritable CD (CD-RW) was developed by Philips and Sony in 1996, as an extension to the original Orange Book. This addition specifies the use of Phase Change technology and the UDF to produce a CD that can be

	rewritten in one pass. CD-RW makes it possible for the user to write and rewrite the disk.
White Book	The White Book, which was released in 1993 by Sony, Philips, Matsushita, and JVC, is the specification document for Video CD (VCD), and encompasses specifications for track usage, MPEG audio/video track encoding, play sequence descriptors, data retrieval structures, and user data fields. VCD is defined as a particular adaptation of CD-ROM XA (extended architecture) that is designed to hold MPEG-1 video data. The CD-ROM XA sector structure (as detailed in the Yellow Book and ISO 9660) is used to define the physical and logical blocks, and MPEG-1 is used to compress data so that full-screen, full motion video data can be contained on the disc - without compression, the disc could only hold about 2 minutes worth of video. VCD resolution is similar to that of VHS. White Book specifications include the disc format (such as the use of tracks, for example), a data retrieval structure compatible with ISO 9660, data fields to enable fast forward and reverse, and closed captioning. VCD, Photo CD and Karaoke CD are defined as bridge disks, a format based on CD-ROM XA to enable the disks to work in compatible CD-ROM and CD-i (CD-Interactive) drives. Following the original specifications, VCD 2.0 was released in 1995, VCD-Internet in 1997, and SuperVCD in 1998, all from extensions to the White Book. Disks of this type interleave MPEG video and audio to achieve proper data flow rates.

Green Book	The Green Book (sometimes known as the Full Functional Green Book, or FFGN) is the informal name for Philips and Sony's 1986 specification document for CD-Interactive (CD-i). More properly known as the *Compact disc Interactive Full Functional Specification* , the document defines a compact disc format and a complete hardware and software system with specialized data compression and interleaving techniques. The Green Book comprises both the CD-i specification and the Microware OS-9 2.4 (the specified operating system) Technical Manual. CD-i was introduced as an interactive multimedia system that could be connected to the television and stereo system and was the first such system based on CD technology. The Green Book specifies track layout, sector structure, and an ISO 9660-based data retrieval structure. Adaptive differential pulse-code modulation (ADPCM) is used to convert sound to binary information and to store it along with other types of media data. Green Book block structure enables synchronization of the various kinds of data and file compression for multimedia applications. CD-i sectors make use of an 8 byte area left unused by CD-ROM XA, although they are similar otherwise.
Blue Book	The Blue Book is the informal name for the standard specification document for *stamped multisession* (also known as *enhanced CD* or E-CD) disc format, developed in 1995 from a supplement to Philips and Sony's 1988 Orange Book. The Blue Book defines a format for enhanced CDs that enables inclusion of multimedia data (such as video clips, text, and images) on a standard audio CD. Blue Book disc specifications include audio and other data sessions, directory structures, and image and

	data formats. The disks play normally on a CD-player, and display the extra data when they are played on a device with multimedia capabilities, such as a computer's CD-ROM drive, or a CD-i player. The Blue Book specifies two sessions: up to 99 Red Book audio tracks in the first session (closest to the center of the disk), and a Yellow Book-based data track in the second session (closest to the outside edge of the disk). Other Blue Book details include the Red Book disc specification, file formats (including CD Plus information files), and an ISO 9660-compatible directory structure to organize the various types of data. The Blue Book is supported as a licensed standard definition by Philips, Sony, Microsoft, and Apple. A multisession CD, the CD+ is designed so that the data track cannot be accessed by regular audio CD players, thereby protecting them for damage.
Scarlet Book	The Scarlet Book is Philips and Sony's 1999 specification document for Super Audio Compact disc (SACD), a high-resolution audio format that features complex six channel sound. SACD disks can contain three different versions of the same material. SACD uses Direct Stream Digital (DSD) recording, a proprietary Sony technology that converts an analog waveform to a 1-bit signal for direct recording, instead of the pulse code modulation (PCM) and filtering used by standard CDs. DSD uses lossless compression (so-called because none of the data is lost in the compression process) and a sampling rate of 2.8MHz to improve the complexity and realism of sound. DSD enables a frequency response of 100kHz and a dynamic range of 120dB (the ratio of the softest to the loudest

	sound - 120db is also the approximate dynamic range of human hearing) on all channels. Scarlet Book details include three separate options for disc format: single-layer DSD, dual-layer DSD, or dual-layer hybrid, which includes a Red Book layer that can be played on any existing CD player in addition to the high-density layer that has the capacity to deliver eight channels of DSD. In addition to DSD and the hybrid disc technology, Scarlet Book specifications include: Super Bit Mapping Direct, a proprietary downconversion method that enables improved audio when the disks are played on an ordinary CD player; Direct Stream Transfer, a type of coding that increases data capacity; and a digital watermark to protect against piracy. According to some, SACD is a hybrid CD/DVD format, since Scarlet Book specifications are identical to those for DVD disks for the file system, sector size, error correction, and modultation. SACD is in competition with a similar product, DVD-Audio, as the format that will replace standard audio CD.
Purple Book	The Purple Book is the informal name for Philips and Sony's specification document for Double Density Compact disc (DDCD) format. By narrowing the track pitch (to 1.1 micron from 1.6 micron), and shortening the minimum pit length (to 0.623 micron from 0.833 micron), the Purple Book enables a CD to hold 1.3 gigabytes, roughly twice the capacity of a standard CD. Other Purple Book specifications include a new type of error correction (known as *CIRC7*), an adaptation of the ISO 9660 file format, and a scanning velocity of 0.9 meters per second.

	The Purple Book-defined products are expected to be released in recordable and rewritable formats, rather than read-only. Because of the specific requirements for reading DDCD, they cannot be read by other drives currently on the market. Sony has plans to manufacture DDCD-R/RW drives that can read any type of CD, record CD-R, rewrite CD-RW, and perform all three tasks on DDCD. Some upcoming CD-R and CD-RW drives, such as Adaptec's new version of Easy CD Creator, are being designed to be DDCD-compatible.
ISO 9660	ISO (International Organization for Standardization) 9660 is the most common file and directory naming standard, written in 1988 for CD-ROMs. **Naming convention** - Each file name must consist of three components: name, extension and version number. A name *or* extension consists of zero or more characters [A...Z], [0...9] and _ (underscore). The version number ranges from 1 to 32767. The name and extension *together* must consist of at least one character e.g. .000:1 is a valid ISO-9660 file name. **Interchange Levels** - Three nested, downward-compatible levels are used to record and name files on the CD ROM disk. Level 1 - Developed with DOS file naming limitations in mind, restricts filenames to 8 characters and extensions to 3 characters. Directory names can have no more than 8 characters. Each file must be written on disc as a single, continuous stream of bytes. Level 2 - Each file must be written on disc as a single, continuous stream of bytes. According

	to AXIS Corporation, no restrictions are placed on filenames; According to Global Net Systems (GNS), the total length of the name and extension is restricted to 30 characters (excluding the point and semicolon). Level 3 - Again, according to the AXIS Corporation, there are no restrictions; according to GNS, filenames and extensions cannot exceed 30 characters.
Joliet	The Joliet Specification is an extension of ISO 9660, and was developed by Microsoft for Windows 95. It allows CDs to be recorded using long filenames (up to 64 characters in length, including spaces). It also allows the use of the Unicode international character set.
Rock Ridge Standard	The Rock Ridge Standard goes beyond the ISO 9660 specification and is applicable to UNIX operating systems. It allows longer file names with more complex character sets and symbolic links for files.
ISO/IEC 13490-1:1995	"Information technology -- Volume and file structure of read-only and write-once compact disc media for information interchange -- Part 1: General," (ISO, http:www.iso.ch)
ISO/IEC 13490-2:1995	Information technology -- Volume and file structure of read-only and write-once compact disc media for information interchange -- Part 2: Volume and file structure, (ISO, http:www.iso.ch)

CD-DA (Compact Disk-Digital Audio)

CD-DA (Compact Disk-digital audio), the original compact disc for music, was defined in the Red Book by Philips and Sony, in 1982. The CD-DA allows a music playing time of 74 minutes

30 seconds. Data on a CD-DA is organized into logical blocks of information. The audio information is stored in frames of 1/75 second length. There are 44,100 samples per second stored. Each sample occupies two bytes (16bits) and there are two channels (left and right) stored on the CD-DA. This gives a sector size of 2,352 bytes per frame, which is the total size of a physical block on a CD.

CD-ROM (Read-Only-Memory)

CD-ROM (Compact Disk, read-only-memory) is an adaptation of the CD that is designed to store computer data in the form of text, video, and graphics, as well as stereo sound. The original data format standard was defined by Philips and Sony in the Yellow Book. Other standards are used in conjunction with it to define directory and file structures, including ISO 9660, HFS (Hierarchal File System, for Macintosh computers), and Hybrid HFS-ISO. Format of the CD-ROM is the same as for audio CDs: a standard CD is 120 mm (4.75 inches) in diameter and 1.2 mm (0.05 inches) thick and is composed of a polycarbonate plastic substrate (underlayer - this is the main body of the disk), one or more thin reflective metal (usually aluminum) layers, and a lacquer coating.

High Sierra Format (HSF)

The Yellow Book specifications were so general that there was some fear in the industry that multiple incompatible and proprietary formats would be created. In order to prevent such an occurrence, representatives from industry leaders met at the High Sierra Hotel in Lake Tahoe to collaborate on a common standard. Nicknamed the *High Sierra Format* , this version was later modified to become ISO 9660. Today, CD-ROMs are standardized and will work in any standard CD-ROM drive. CD-ROM drives can also read audio compact disks for music, although CD players cannot read CD-ROM disks.

CD-ROM Data Storage

Although the disc media and the drives of the CD and CD-ROM are, in principle, the same, there is a difference in the way data storage is organized. Two new sectors were defined, Mode 1 for storing computer data and Mode 2 for compressed audio or video/graphic data.

CD-ROM Mode 1

CD-ROM Mode 1 is the mode used for CD-ROMs that carry data and applications only. In order to access the thousands of data files that may be present on this type of CD, precise addressing is necessary. Data is laid out in nearly the same way as it is on audio disks: data is stored in sectors, which each hold 2,352 bytes of data, with an additional number of bytes used for error detection and correction, as well as control structures. For mode 1 CD-ROM data storage, the sectors are further broken down, and 2,048 used for the expected data, while the other 304 bytes are devoted to extra error detection and correction code, because

CD-ROMs are not as fault tolerant as audio CDs. There are 75 sectors per second on the disk, which yields a disc capacity of 681,984,000 bytes (650MB) and a single speed transfer rate of 150 KBps, with higher rates for faster CD-ROM drives. Drive speed is expressed as multiples of the single speed transfer rate, as 2X, 4X, 6X, and so on. Most CD-ROM drives support CD-ROM XA and Photo-CD (including multisession disks).

CD-ROM Mode 2

CD-ROM Mode 2 is used for compressed audio/video information and uses only two layers of error detection and correction, the same as the CD-DA. Therefore, all 2,336 bytes of data behind the sync and header bytes are for user data. Although the sectors of CD-DA, CD-ROM Mode 1 and Mode 2 are the same size, the amount of data that can be stored varies considerably because of the use of sync and header bytes, error correction and detection. The Mode 2 format offers a flexible method for storing graphics and video. It allows different kinds of data to be mixed together, and became the basis for CD-ROM XA. Mode 2 can be read by normal CD-ROM drives, in conjunction with the appropriate drivers.

Data Encoding and Reading

The CD-ROM, like other CD adaptations, has data encoded in a spiral track beginning at the center and ending at the outermost edge of the disk. The spiral track holds approximately 650 MB of data. That's about 5.5 billion bits. The distance between two rows of pits, measured from the center of one track to the center of the next track is referred to as track pitch. The track pitch can range from 1.5 to 1.7 microns, but in most cases is 1.6 microns.

Constant Linear Velocity (CLV)

Constant Linear Velocity is the principle by which data is read from a CD-ROM. This principal states that the read head must interact with the data track at a constant rate, whether it is accessing data from the inner or outermost portions of the disk. This is affected by varying the rotation speed of the disk, from 500 rpm at the center, to 200 rpm at the outside. In a music CD, data is read sequentially, so rotation speed is not an issue. The CD-ROM, on the other hand, must read in random patterns, which necessitates constantly shifting rotation speeds. Pauses in the read function are audible, and some of the faster drives can be quite noisy because of it.

CD-R

CD-R (for *Compact Disk, recordable*) is a type of *write once, read many*(WORM) CD format that allows one-time recording on a disk. The CD-R (as well as the CD-RW) format was introduced by Philips and Sony in their 1988 specification document, the Orange Book. Prior to the release of the Orange Book, CDs had been read-only audio (CD-Digital Audio, detailed in the Red Book), to be played in CD players, and multimedia (CD-ROM), to be played in computers' CD-ROM drives; after the Orange Book, any user with a CD recorder drive could create their own CDs from their desktop computers.

CD-Rs are composed of a polycarbonate plastic substrate, a thin reflective metal coating, and a protective outer coating. However, in a CD-R, a layer of organic polymer dye between the polycarbonate and metal layers serves as the recording medium. The composition of the dye is permanently transformed by exposure to a specific frequency of light. Some CD-Rs have an additional protective layer to make them less vulnerable to damage from scratches, since the data - unlike that on a regular CD - is closer to the label side of the disk. A pregrooved spiral track helps to guide the laser for recording data, which is encoded from the inside to the outside of the disc in a single continuous spiral. The laser creates marks in the dye layer that mimic the reflective properties of the*pits* and *lands* (lower and higher areas) of the traditional CD. The distinct differences in the way the areas reflect light register as binary data that is then unencoded for playback.

CD-R disks usually hold the standard 74 minutes (650MB) of data, although some can hold up to 80 minutes (700MB). With packet writing software and a compatible CD-R or CD-RW drive, it is possible to save data to a CD-R in the same way as one can save it to a floppy disk, although - since each part of the disc can only be written once - it is not possible to delete files and then reuse the space. The rewriteable CDs, CD-RWs, use an alloy layer (instead of the dye layer) which can be transformed to and from a crystalline state repeatedly.

CD recorders (usually referred to as CD burners), were once much too expensive for the home user, but now are similar in price to CD-ROM drives. CD-Rs can be created in any CD-R or CD-RW drive.

CD-RW

CD-RW (for *Compact Disk, rewriteable*) is a CD format that allows repeated recording on a disk. The CD-RW format was introduced by Hewlett-Packard, Mitsubishi, Philips, Ricoh, and Sony, in a 1997 supplement to Philips and Sony's Orange Book. CD-RW is Orange Book III (CD-MO was I, while CD-R was II). CD-RW drives can write both CD-R and CD-RW disks and can read any type of CD.

Unlike CD-R, in which is a layer of organic polymer dye (which is permanently changed by the laser) serves as the recording medium, in a CD-RW, the dye is replaced with an alloy that can change back and forth from a crystalline form when exposed to a particular light, through a technology called phase change. The patterns created are less distinct than those of other CD formats, requiring a more sensitive device for playback. Only drives designated as "MultiRead" are able to read CD-RW reliably.

Similar to CD-R, the CD-RW's polycarbonate substrate is preformed with a spiral groove to guide the laser. The alloy phase-change recording layer, which is commonly a mix of silver, indium, antimony and tellurium, is sandwiched between two dielectric layers that draw excess heat from the recording layer. After heating to one particular temperature, the alloy will become crystalline when it is cooled; after heating to a higher temperature it will become amorphous (won't hold its shape) when it is cooled. By controlling the temperature of the laser, crystalline areas and non-crystalline areas are formed. The crystalline areas will reflect the laser, while the other areas will absorb it. The differences will register as binary data that can be unencoded for playback. To erase or write over recorded data, the higher temperature laser is used, which results in the non-crystalline form, which can then be reformed by the lower temperature laser.

CD-RW disks usually hold 74 minutes (650MB) of data, although some can hold up to 80 minutes (700MB) and, according to some reports, can be rewritten as many as 1000 times. With packet writing software and a compatible CD-RW drive, it is possible to save data to a CD-RW in the same way as one can save it to a floppy disk. For a CD to record correctly, it is crucial for a steady data stream to be created. Typically, the drives have a 2MB cache, used as a buffer. If the buffer runs out of data during the writing process, the CD produced will be unusable.

CD-ROM XA

CD-ROM XA (Compact disc - read-only-memory, extended architecture) is a modification of CD-ROM that defines two new types of sectors that enable it to read and display data, graphics, video, and audio at the same time. CD-ROM XA was developed jointly by Sony, Philips and Microsoft, and its specifications were published in an extension to the Yellow Book.

CD-ROM XA (for eXtended Architecture) disks contain Mode 2 sectors (areas left free for extra data by the omission of error detection and correction code) and were designed to allow audio and other data to be interleaved (stored in a mixed format rather than separately) and read simultaneously. Formerly, images had to be loaded before the audio tracks could be played. The CD-ROM XA specifications include 256 color modes, which are compatible with PC formats and CD-I, and Adaptive Differential Pulse Code Modulation (ADPCM) audio, which is also defined for CD-I. Photo CD, Video CD and CD-EXTRA have all subsequently been based on CD-ROM XA, although it has not survived as a separate technology. p>

CD-ROM XA disks can mix standard CD-ROM, Mode 1 and CD-ROM, Mode 2 tracks. The mode 2 tracks are divided into two additional types, Form 1 and Form 2. CD-ROM XA disks usually must be read by drives certified to decipher the CD-ROM XA format. These drives will probably contain hardware decoders that will allow decompression of compressed audio or video files.

The two logical block sizes on the CD-ROM XA are:
1. 2048 bytes per block for data
2. 2324 bytes per block for audio/video information

CD-i

CD-i (Compact disc - interactive) is a multimedia CD format specified in 1986, in the Green Book. CD-i was detailed as a whole system, comprising not just a disc and data format, but an entire hardware and software system, a variety of special compression methods for audio and visual data, and a method of interleaving audio, video, and text data. Developed as a user-friendly alternative to a PC, CD-i players are easier to use, and have TV video output as well. Full screen motion video capabilities were added to the original specification later.

A CD-i player is a stand-alone system that comprises CPU, memory and an integrated operating system. It can be connected to a TV-set for displaying pictures and sound, or to a stereo system. The user interacts by positioning a cursor and selecting options, with a device such as a specialized remote control.

Although CD-i never realized broad commercial success, it is now used in the education system, and for training and other professional applications.

Bridge Disks

A CD-Bridge disc (sometimes just called a *bridge disk*) is a CD format that includes extra information on a CD-ROM XA track, so that the disc can be played on either a CD-i player attached to a television, or a CD-ROM XA drive attached to a computer. A bridge disc with appropriate application software may also play on other XA-compatible devices, such as a Photo CD or Karaoke CD player. Video CD (VCD), Photo CD, and Karaoke CD are three bridge disc formats.

CD-Bridge disc specifications are built on those from the Yellow Book extension, which defined CD-ROM XA, and the Green Book, which defined CD-i, and must conform to the complete requirements of both formats. The complete CD-Bridge disc definition is detailed in the White Book, which was released by Sony, Philips, Matsushita, and JVC in 1993.

Enhanced CD

Enhanced CD (E-CD) is a CD format that enables disks to be played on either a CD player or a multimedia-capable device, such as a CD-i player,or a DVD-ROM, or CD-ROM drive, where added material can be displayed. E-CD, technically known as *stamped multisession* , is used to refer to any audio CD that has CD-ROM data added. Most audio CDs use only about 60 minutes-worth of the disk's 74 available minutes-worth of space; E-CD takes advantage of the unused space to include extra data on audio CDs. Recording artists have used E-CD technology to include video clips, artist profiles, lyrics, interviews, animation, promotional material, and even games on audio disks.

E-CD specifications are detailed in the Blue Book, a 1995 supplement to the 1988 Philips and Sony Orange Book, that was intended as a separate definition for stamped multisession disc format. Because the disks are stamped (pressed from copies of the original recording), they are not user-recordable. The Blue Book, which called the new format *CD Plus*specified two recording sessions, one for audio data and one for any other included data. Like all CD formats, enhanced CD is based on the original Red Book specifications. E-CD is sometimes called *CD-Extra, CD-Plus, stamped multisession* , or simply *Blue Book format* .

E-CD format is designed to overcome the problems of *mixed-mode* CDs, which also consisted of separate tracks for audio and other data. Mixed-mode disks were often responsible for speaker damage: when a CD player tried to read the data tracks, the result was loud static. Because E-CD data and audio tracks are written in separate sessions, the data track(s) can be made invisible to the CD player, so that only the audio tracks are played.

CD-MO (Magneto-Optical)

Compact disc - Magneto Optical (CD-MO) is a CD format that uses magnetic fields for data storage. Defined by Philips and Sony in their 1990*Recordable CD Standard* , (informally known as the Orange Book) CD-MO disks can, at least theoretically, be rewritten an unlimited number of times.

CD-MO disks are constructed of an alloy of terbium ferrite and cobalt. The reading of an MO disc is based on the Kerr effect. (In the Kerr effect, linear, polarized light is deflected when it is influenced by a magnetic field, and the plane of polarization is twisted.) The MO method changes the magnetic characteristics of tiny areas on the disk's surface so that the reading laser beam is reflected differently on altered areas than on unaltered areas.

When writing to the disk, a laser beam is focused on an extremely small spot, and the alloy is heated to a specific temperature (called the *Curie point*) sufficient to cause the ferromagnetic properties of the aligned elementary particles to be lost. An electromagnet is positioned on the other side of the disk, changing the polarity of the particles, whose differences will be encoded as binary data for storage. Like other optical media, such as DVD and other CD formats, CD-MO is read by a laser beam, which makes it more reliable than a hard disc or a floppy disk. However, a strong magnetic field can corrupt the stored data.

Multisession CD

A Multisession CD is a recordable CD (like a CD-R) that allows data to be recorded to a disc in more than one recording session. If there is free space left on the CD after the first session, additional data can be written to it at a later date. Every session has its own lead in, program area, and lead out. This takes up about 20MB of space, and therefore, is less efficient than recording data all at once.

Multisession CDs can be read in current CD-ROM drives, unless data is recorded track-by-track or sector by sector. This process is known as packet writing and in this case only newer CD-ROM drives accompanied by appropriate software would be able to read the disk.

Super Audio CD (SACD)

Super Audio Compact disc (SACD) is a high-resolution audio CD format. Version 1.0 specifications were detailed by Philips and Sony in March of 1999, in the Scarlet Book. SACD and DVD-Audio (DVD-A)are the two formats competing to replace the standard audio CD. Most of the industry is backing DVD-A, with Philips and Sony being the major exceptions.

Like SACD, DVD-A offers 5.1 channel surround sound in addition to 2-channel stereo. Both formats improve the complexity of sound by increasing bit rates and sampling frequencies, and can be played on existing CD players, although only at quality levels similar to those of traditional CDs. SACD uses Direct Stream Digital (DSD) recording, a proprietary Sony technology that converts an analog waveform to a 1-bit signal for direct recording, instead of the pulse code modulation (PCM) and filtering used by standard CDs. DSD uses lossless compression (so-called because none of the data is lost in the compression process) and a sampling rate of 2.8MHz to improve the complexity and realism of sound. SACD can also contain extra information, such as text, graphics, and video clips.

The first SACD player was released in North America in December of 1999, with an $8000 price tag. In late 2000, Sony released a new model, priced at $1000.

Double Density CD (DDCD)

Double Density Compact disc (DDCD) is a CD format that increases the storage capacity of the disc through means such as increasing the number of tracks and pits. Philips and Sony detailed the DDCD specifications in their 2000 document (known informally as the Purple Book).

Although DDCD did not receive much industry notice until Philips and Sony produced the Purple Book specifications, the Optical disc Corporation (ODC) released a similar format, High Density CD (HDCD) in 1993, and Nimbus Technology and Engineering introduced their own Double Density CD format in 1994. The general feeling in the industry is that DDCD has been introduced as a stop-gap measure to tide over the market until DVD inevitably solves its problems (such as standardization and compatibility issues) and completely obliterates the CD.

DVD (Digital Versatile Disk)

DVD is a relatively new optical disc technology that uses denser recording techniques in addition to layering and two-sided manufacturing to achieve very large disc capacities. DVDs can hold video, audio and computer data. DVD drives are also able to read CD-ROMs. The original purpose of DVD was to hold video data in particular - DVD once was said to stand for *Digital Video Disk* . However, as the number of DVD applications grew, the variety of data that can be stored on DVD was reflected in its present name, Digital Versatile disc (although some claim that it should be referred to only by the three letters, DVD).

Also a 4.7 inch diameter (120 mm) by .05 inch (1.2mm) thick disk, the DVD stores data on a spiral track like the CD. The wave length of the laser beam used to read the DVD disc is shorter than that used for standard CDs. The DVD disc is created with shallower and smaller indentions, thereby enabling greater storage capacity.

In addition, there are more tracks per disc on DVDs, because they are placed closer together than on CDs. The track pitch has been reduced to 0.74 microns. This is less than half that of CDs, which is 1.6 microns. Data pits are considerably smaller, which allows a greater number per track than on CDs. The average DVD disc holds 4 times the number of data pits that can be held by a CD. The average capacity of a single-sided, single-layered disc is 4.7 gigabytes. DVD has also increased the efficiency of the data structure on the disk. In the 1970s, when CDs were first developed, considerable error correction was necessary to ensure that the disc would play correctly. More bits were being used for error detection and correction, which limited the disk's capacity to carry user data. DVD's more efficient error correction code (ECC) allows increased capacity for user data.

The larger number of data pits on a DVD is accomplished by shortening the wavelength of the laser used to create the pits. The wavelength was reduced from 780nm (nanometers), infrared light, for the CD, to 635nm to 650nm, red light, for the DVD. *Synchronization* ensures that both audio and video portions of the DVD are presented to the user simultaneously (at the same time), an important aspect of digital movie playback architecture.

Double-Layered DVD Disks

DVD disks can also be constructed with two layers. On a double-layered disk, each data layer is half as thick as that used in the CD-ROM. Data can, therefore, be written in two layers. The outer layer is semi transparent to allow reading of the underlying silver layer. The reading laser operates at two different intensities, the stronger one reads the inner, silver layer. This increases the storage capacity to 8.5 Gb of data and eliminates the necessity of removing and flipping the disk.

An additional feature that improves efficiency is the dual-directional readability of the second data layer. Unlike standard-density CD-ROMs, which can only be read from the innermost part of the spiral track to the outermost part, the second layer of the double-layered DVD can be written to and read from either direction. This results in faster transitions by the reading laser. It can actually take less time for the reading laser to refocus to retrieve data from a different layer on a DVD than it does for the laser to relocate and retrieve data from a different part of the same layer on a CD-ROM.

An extension of the double-layered disc is the double-sided DVD disk. To enable the refocusing of the read laser, manufacturers have constructed DVD disks with a thinner plastic substrate than that used on a CD-ROM disk. This reduces the distance that the laser must travel to reach the data pits. The resulting disks were only 0.6mm thick, too thin to remain flat and withstand handling. Two disks were then bonded back-to-back resulting in a thickness of 1.2mm, a manageable thickness. This virtually doubled the disc capacity.

DVD Versions and Storage Capacity

Unlike standard CDs, DVD disks have varying storage capacities, expressed as a numeral.

DVD Version	Description and Storage Capacity
DVD-5	Single-sided, single-layered disc with 4.7Gb capacity
DVD-9	Single-sided, double-layered with 8.5Gb capacity
DVD-10	Double-sided, single-layered disc with 9.4Gb capacity
DVD-18	Double-sided, double-layered disc with 17Gb capacity

DVD Regional Codes

In an effort to control the home release of movies in different countries, motion picture studios have devised a method to prevent playback of certain disks in certain geographical regions. Since theatre releases are not simultaneous, and because studios sell distribution rights to foreign distributors and would like to guarantee exclusive markets, pressure was brought to bear on the writers of the DVD standard. The standard now includes codes that can be used in playback devices to ensure that only disks purchased in the same geographical areas as the players will function properly.

Regional codes are entirely optional for disc manufacturers, however. disks without codes will play on any player regardless of its origin. One byte of information holding the regional code can be checked by the player. There is no encryption involved, but regional codes are a permanent part of the disc with no unlocking mechanism included. Although manufacturers originally planned to code only new releases, most DVD disks today are geographically coded.

The DVD Forum

The DVD Forum is an international organization made up of companies using or manufacturing DVD - related products. The Forum, which was originally called the DVD Consortium, was created in 1995 when ten companies (Hitachi, Matsushita, Mitsubishi, Philips, Pioneer, Sony, Thomson Multimedia, Time Warner, Toshiba Corporation, and Victor) joined for the common purpose of promoting DVD worldwide, establishing single formats of each DVD application for the marketplace, and addressing the issues threatening DVD acceptance, such as standardization and device compatibility issues. From ten founding members, the DVD Forum membership has grown to include some 230 companies worldwide. The Forum's activities are directed by a steering committee that is elected every second year. Separate working groups are established to define specifications. A Verification Task Force (VTF) exists to define test specifications, tools, and procedures to be used and to ensure that products bearing the official DVD logo comply with all specifications. The DVD defines as its purposes, to:

1. Define DVD Format specification
2. Publish reference material and newsletters for members
3. Publish DVD Format Books (through DVD Format/Logo Licensing Corporation)
4. License DVD Format/Logo (through DVD Format/Logo Licensing Corporation)
5. Administer DVD Verification Laboratories
6. Hold worldwide DVD Conferences, promote PR activities, and operate the Forum Homepage.

DVD Specifications

Specification Document	Contents of Specification Document
Book A	The first of three read-only specifications, DVD-ROM holds computer data and is read by a DVD-ROM drive, hooked up to a computer. It is a high-capacity data storage medium. The

	data stored can also be feature-length films, but they must be displayed on the computer monitor.
Book B	1998 - The second of the three read-only formats, DVD-Video holds video data (such as movies) and is played on a DVD player hooked up to a TV. It is a digital storage medium primarily used for feature-length films.
Book C	Third of the three read-only formats, DVD-Audio is a high-resolution audio-only storage format similar to Super Audio CD (SACD)
Book D	The first writable DVD format, DVD-R is a write-once, read-many storage format, similar to CD-R
Book E	The second of the writable DVD formats, DVD-RAM must be handled in special devices, which do not fit into ordinary DVD drives.
Book F	The third of the writable DVD formats, DVD-RW allows DVDs to be written and erased repeatedly, similarly to CD-RW.

DVD Formats

Although DVD was once thought of as being solely a video format, there are several other DVD specifications:

DVD-ROM

Digital Versatile disc - Read Only Memory (DVD-ROM) is a DVD format with technology similar to the familiar DVD video disk, but with a more computer-friendly file structure. The DVD-ROM format was designed to store the same type of computer data typical of a CD-ROM, and is intended for use in DVD-ROM drives in a personal computer. DVD-ROMs have seven times the storage capacity of CD-ROMs. DVD-ROM specifications were detailed in the original 1997 document, Book A.

DVD-ROM is sometimes described as a "bigger bit bucket," meaning that it is a larger storage space, and one that can be filled with whatever the user chooses, such as video, music, or computer-specific data. A DVD-ROM drive is similar to the CD-ROM drive, but with enhanced optical engineering that enables it to read the greater data load. DVDs, although the same size as CDs, have varying storage capacities of up to 17GB (this is a format called DVD-18), compared with the standard CD's approximate (and unvarying) capacity of 750MB. DVDs increase the numbers of pits and lands (lower and higher areas on the disc that are read by the laser and recorded as binary data) by decreasing both the size of the pits and the track pitch (space between tracks). In order to read the data from the smaller pits, the laser wavelength used by DVD-ROM drives was also reduced significantly.

DVD-ROM drives have a base speed of 1.32 megabytes/second; specific drive speeds are expressed as multiples of base, in the same way that CD-ROM drives are. DVD-ROM drives are backward compatible, and can read CD-ROMs, usually at speeds comparable to a 24X or 32X CD-ROM drive. The DVD-ROM drive - which is being manufactured by most makers of CD-ROM drives - is expected to replace the CD-ROM in the near future.

DVD-RAM

Digital Versatile disc - Random Access Memory (DVD-RAM) is an adaptation of DVD-ROM that uses magneto-optical technology to record data, both on the grooves and the lands (flat areas) of the disk. DVD-RAM specifications, known as Book E, were released by the DVD Forum in 1998. Like most DVD formats, DVD-RAM can contain any type of information, such as video, text, audio, and computer data; however, at 2.6 gigabytes, the storage capacity is much lower than the other types of DVD. Single-sided DVD-RAM disks can be read by DVD-ROM drives, but double-sided DVD-RAM disks are not compatible with most DVD-ROM drives. Hitachi's DVD-RAM drive was introduced in 1998. The Hitachi drive could record and play single and double-sided DVD-RAM disks and could play CD-ROM, CD-R, CD-RW, and audio CDs .

DVD-Audio

DVD-Audio (DVD-A) is a DVD format developed by Panasonic that is specifically designed to hold audio data, and particularly, high-quality music. The DVD Forum released the final DVD-A specification in March of 1999. The new DVD format is said to provide at least twice the sound quality of audio CD on disks that can contain up to seven times as much information. Various types of DVD-A-compatible DVD players are being manufactured, in addition to the DVD-A players specifically developed for the format.

Almost all of the space on a DVD video disc is devoted to containing video data. As a consequence, the space allotted to audio data, such as a Dolby Digital 5.1 soundtrack, is severely limited. A lossy compression technique - so-called because some of the data is lost - is used to enable audio information to be stored in the available space, both on standard CDs and DVD-Video disks. In addition to using lossless compression methods, DVD-A also provides more complexity of sound by increasing the sampling rate and the frequency range beyond what is possible for the space limitations of CDs and DVD-Video. DVD-Audio is 24-bit, with a sampling rate of 96kHz; in comparison, DVD-Video soundtrack is 16-bit, with a sampling rate of 48kHz, and standard audio CD is 16-bit, with a sampling rate of 44.1kHz.

Although DVD-A is designed for music, it can also contain other data, so that - similarly to Enhanced CD - it can provide the listener with extra information, such as liner notes, and images. A variation on the format, DVD-AudioV, is designed to hold a limited amount of conventional DVD video data in addition to DVD-Audio. DVD-A is backed by most of the industry as the technology that will replace the standard audio CD. The major exceptions are Philips and Sony, whose Super Audio provides similar audio quality. Like DVD-A, SACD offers 5.1 channel surround sound in addition to 2-channel stereo. Both formats improve the complexity of sound by increasing bit rates and sampling frequencies (among other techniques), and can be played on existing CD players, although only at quality levels similar to those of traditional CDs.

DVD-R

Digital Versatile disc - Recordable (DVD-R) is a type of *write once, read many* (WORM) DVD format that allows the user to record a single time on a DVD disk. DVD-R specifications, known as Book D, were released by the DVD Forum in 1997. Similarly to CD-R, DVD-R can contain any type of information, such as video, text, audio, and computer data, for example. DVD-R disks can be played on any type of DVD playback device that can handle the type of information stored, such as a DVD-ROM drive, or a DVD video player. DVD-R disks are read at the same speeds as commercially made DVDs.

DVD-R recording, like CD-R recording, is enabled by the use of a layer of organic dye that is permanently changed by exposure to a finely focused laser beam. The dye layer is coated onto the DVD's base layer, a polycarbonate plastic substrate (the base layer of all CDs and DVDs), which is injection molded, and has a pre-grooved spiral track on its surface to guide the laser. To increase the storage capacity of DVDs, both the wavelength and aperture size of the laser are decreased so that smaller pits (the areas read by the laser to obtain binary data) can be created - reading the disc also requires the same changes. Once the data has been written, the dye layer is coated with a thin, reflective metal coat that will enable the laser to read data from the differences in the way pits and lands reflect light. DVD-Rs can be written in a single session (called write-at-once recording) or incrementally, in a process similar to the packet writing technology used for CD-Rs.

DVD-RW

Digital Versatile disc - Rewritable (DVD-RW) is a DVD format that allows the user to record and erase multiple times on a single DVD disk. DVD-RW specifications were released as Book F in 1999 by the DVD Forum. A slightly different rewritable DVD format, DVD+RW is backed by a group of companies known as the DVD+RW Consortium, made up of Philips, Sony, Hewlett-Packard, Mitsubishi Chemical, Yamaha, and Ricoh.

Similarly to CD-RW and DVD-R, DVD-RW can contain any type of information, such as video, text, audio, and computer data, for example. DVD-RW disks can be played on any type of DVD playback device that can handle the type of information stored, such as a DVD-ROM drive, or a DVD video player. Like DVD-R, DVD-RW disks can hold up to 9.4 gigabytes of data, compared to the 650 megabyte capacity of the CD.

DVD-RW recording is similar to CD-RW recording, just as the one-time recording format, DVD-R, has a similar process to that of CD-R. The basic structure of all CDs and DVDs - a polycarbonate substrate, a thin, reflective metal layer, and a protective outer layer - is the same. In the case of the one-time recording formats, an organic dye layer (which is permanently changed by exposure to a finely focused laser) serves as the recording medium. In a DVD-RW, the dye layer is replaced with an alloy that can change back and forth from a crystalline form when exposed to a particular light, through a technology called phase change. The patterns created are less distinct than those of other CD formats, requiring a more sensitive device for playback.

Similarly to DVD-R, the DVD-RW's polycarbonate substrate is preformed with a spiral groove to guide the laser. The alloy phase-change recording layer is sandwiched between two dielectric layers that draw excess heat from the recording layer. After heating to one particular temperature, the alloy will become crystalline when it is cooled; after heating to a higher temperature it will become amorphous (won't hold its shape) when it is cooled. By controlling the temperature of the laser, crystalline areas and non-crystalline areas are formed. The crystalline areas will reflect the laser, while the other areas will absorb it. The differences will register as binary data that can be unencoded for playback. To erase or write over recorded data, the higher temperature laser is used, which results in the non-crystalline form, which can then be reformed by the lower temperature laser.

The Future of CD/DVD Technology

Although there are still compatibility and standardization issues to settle - and a few challenges from some of the newer CD formats - most industry members predict that DVD, which has greater storage capacities and faster access times, will replace CD technologies in the near future. DVD-ROM drives are likely to be bundled with new computer systems in the way that CD-ROM drives have been. Nevertheless, the future is hard to predict, given the pace of ongoing research and development. The industry moves forward, and newer technologies, such as HD-ROM, are being developed.

HD-ROM (High Density-Read-Only-Memory)

HD-ROM (High-Density - Read Only Memory) is a high capacity storage technology developed at Norsam Technologies, in conjunction with an IBM research group, that enables the discs to store hundreds of times as much information as a CD-ROM. HD-ROM uses a very narrow, finely focused particle beam (consisting of charged gallium ions) to write data. HD-ROM technology can be used to write data on different types of media, such as metal or other durable materials, to create virtually indestructible storage.

HD-ROM's particle beam, at a size of 50 nanometers, enables a storage capacity of 165 gigabytes on disks the same size as a CD or DVD. In comparison, CD-ROM uses an 800-nanometer wavelength laser beam for a storage capacity of 650 megabytes, and DVD-ROM uses a 350-nanometer wavelength laser for a storage capacity of 4.7 gigabytes. HD-ROM was designed to store large databases, such as those required by government agencies, banks, insurance companies, scientific users, and libraries. In addition to the enormous storage capacity, HD-ROM's benefits over traditional archival storage systems (such as magnetic tape and RAID) include faster access times, greater durability, and lower costs.

Media	Beam Width	Capacity per disk
CD-ROM	800 nanometers	0.65 GB
DVD	350 nanometers	4.7 GB
HD-ROM	50 nanometers	165 GB