I. Compact Disc technology

A. Physical formats

1. “Pressed” CDs for long runs
2. “Burnt” CDs for one-offs and short runs
3. Available sizes
   a) 8 cm (3"): audio singles, Sony Dataman
   b) 12 cm (4.72"): standard size
      (1) 63 min. = 283,500 sectors = 553.7 MBytes (Mode 1)
      (2) 74 min. = 333,000 sectors = 650.4 MBytes (Mode 1)

B. Disc playback

1. CDs spin counterclockwise at 200 to 500 revolutions per minute, yielding an almost-constant linear speed of approx. 4 feet per second.
2. The recording is arranged as a single spiral track starting close to the center of the disc.
3. Because of the spiral arrangement, the need to vary the speed of the drive motor, and the comparatively large mass of the laser and optics, CD mechanisms are better suited for sequential reads. Seek times are substantially slower than other random-access storage devices.

C. Error detection and correction

1. Interleaving and Eight-to-Fourteen Modulation (EFM)
   a) Improve reliability of playback process
2. Parity Checking
   a) Detects errors during playback. Multiple parity-checking allows correction of errors (within design specifications).
   b) Combination of multiple parity-checking and interleaving used in CDs is called Cross-Interleave Reed-Solomon Code (CIRC). CIRC allows complete recovery of the data obliterated by a scratch as large as 2.4 mm (approx. 1/10 of an inch).
3. Interpolation
   a) Replaces uncorrectable errors with intermediate values between surrounding valid data.
   b) Interpolation is only acceptable for data with typically smooth variations (sounds, images). Other data (text, numbers, computer programs) require more stringent error correction (with reduced data capacity) to play back with comparable success.

D. Sectors, tracks, and sessions

1. Every CD format is based on *logical sectors* of 3234 bytes.
   a) A sector is the smallest addressable area, using a minutes, seconds, sectors physical address format.
   b) At normal audio speed, drives read 75 sectors per second. Higher speed mechanisms multiply this speed (2x, 3x, etc.) for non-audio tracks only.
   c) Audio CDs set aside 882 bytes of each sector for error correcton and control codes. Other CD formats further reduce data capacity with additional error correction information.
2. Each CD may contain up to 99 distinct data segments called *tracks*.
   a) For audio CDs, each track normally corresponds to a musical selection.
   b) Other CD formats may add generic computer data tracks, as well as special tracks for compressed audio, video, and stills.
3. Each time data is transferred to a CD a *session* is created, possibly containing multiple tracks.

a) Multisession capabilities were introduced by later CD formats. Audio CD players, as well as some older CD-ROM drives, cannot read more than a single session.

b) Sessions must be separated by an *intersession gap*. The gap between the first and second session is 2 minutes and 30 seconds long (22 MBytes). The gap between all subsequent sessions is 1 minute and 30 seconds long (13.2 MBytes).

c) Before a multisession CD can be read by ordinary drives, each session must be closed (this is the process that creates the intersession gap). After closing, it is still possible to add sessions to the disc.

d) Instead of closing the session, the disc may be finalized. This prevents the addition of any further sessions.

(1) Finalizing may be the only option when the disc is almost full, since it does not require writing an intersession gap.

e) When the multisession disc is mounted, it may appear as a single volume ("PhotoCD style") or as multiple volumes, one for each session.

(1) HFS (Macintosh native) discs can only be multivolume. Older versions of the Apple CD-ROM drivers will not work properly with these discs.

E. Data format "color books"

1. Red Book, Digital Audio Compact Disc

a) Provides many specifications shared by later formats. Leaves the most room for user data.

b) Many audio CDs have enough space for 100 to 200 megabytes of computer data, counting subcode bits and unused tracks. Several variants of the audio CD (none too successful) were devised to store additional information in the available space: CD+G (low-resolution graphics for display on TVs), CD+Midi (music data to control electronic instruments).

2. Yellow Book, CD-ROM (Read-Only Memory)

a) Uses the bits encoded on the disc to represent computer data.

b) Mode 1 recording provides additional error correction beyond the CIRC used by the Red Book standard. 2048 bytes per sector are available for data that cannot be interpolated

c) Mode 2 recording (seldom used) does not mandate extra error correction, offering 2336 bytes of user data per sector.

3. Mixed Mode (Data + Audio)

a) Places Yellow Book data on the first track, Red Book audio on following tracks.

b) Since it does not involve multiple sessions, this format may be read by all CD-ROM drives.

c) With appropriate software, the computer can control playback of the audio tracks, providing high-quality accompaniment to a multimedia presentation, regardless of the sound features of the computer.

d) Requires that the user manually skip the first track when playing the CD on an audio device. Unintended audio playback of computer data may damage speakers.

4. Green Book, CD-I (Interactive)

a) Adds two specifications for Mode 2 recording (Form 1 and Form 2), as well as specifying a hardware/software platform for playback.

b) Form 1 is almost identical to Yellow Book Mode 1, and is used for computer data.

c) Form 2 provides 2324 bytes per sector of multimedia content:

(1) Adaptive Delta Pulse Code Modulation (ADPCM) compressed audio, at three quality levels. Over 19 hours of the lowest quality audio can fit on one CD.

(2) Still images.

(3) MPEG-1 video (requires a hardware upgrade to older CD-I players).

d) Both Form 1 and Form 2 sectors include SubHeader information that allows mixing the two Forms in the same track. This can be used to interleave sound, images, and data for optimum playback rates.

5. CD-ROM XA (eXtended Architecture)

a) Extends the Yellow Book standard to include Form 1 and Form 2 recording. Unlike CD-I, it does not mandate specific playback hardware, and is designed for any computer with compatible CD-ROM drive.

b) While CD-ROM XA itself is not widely used, it is the basis for the PhotoCD family of products.

6. Orange Book, CD-R (Recordable)

a) Introduced multiple sessions for incremental recording.

b) Also covers as-yet-unavailable erasable CDs.

7. White Book, Video CD

a) Provides quarter-screen MPEG-1 full-motion video, pixel-doubled to full-screen size.

b) Requires appropriate decompression hardware. Software-only playback may be available in the near future on faster computers.

8. Blue Book, Enhanced CD (a.k.a. CD Plus)

a) First session contains up to 98 Red Book tracks for audio. Also contains brief title and artist information displayed by audio players suitably equipped.

b) The second session, inaccessible to the CD player, contains Yellow Book multimedia content for playback on a computer.

c) Many PC drives require new drivers to access the second session. To circumvent this problem, a variant of Enhanced CD called “Track 0” places the Yellow Book data in an extended pregap to the first audio track, where it is equally invisible to the audio player, but mounts on all CD-ROM drives.

d) Beyond the music market, Enhanced CD may find applications in high-performance games, since Red Book audio does not go through the CPU for playback.

F. File systems

1. “Native” file systems

a) Provide full compatibility with the target computer, undistinguishable from other storage devices used on that platform.

b) Prevents use of the same disc on other kinds of computers. Separate inventories must be produced and stocked for cross-platform titles.

c) The native file format most widely used is the Macintosh Hierarchical File System (HFS), since it is the only way to preserve all the attributes of the Macintosh user interface.

2. “High Sierra” file system, which became—with changes—the ISO 9660 standard

a) Allows placing separate executables for each supported platform on the same disc, with access to shared multimedia content.

b) As it was devised as a minimum common denominator, it may not adequately support desirable features of some platforms. Specific extensions (“Apple” for the Macintosh, “Rock Ridge” for UNIX) mitigate this problem.

c) Legal character set:

(1) Uppercase letters, underscore, numbers, period. The semicolon is only allowed as the separator for the file version number, appended at the end of the filename

d) Maximum directory level depth: 8

e) Maximum file and directory name lengths:

(1) Level 1 interchange specifications: file names 8 characters, file extensions 3 characters, directory names 8 characters (no extension)

(2) Under Level 2 specifications, filenames may be up to 31 characters long. These filenames will be truncated on MS-DOS systems.

3. “Hybrid” (HFS + 9660)

a) Allows each platform to “see” the same data through its preferred file system.

b) The files that are not relevant to one of the platforms may be optionally hidden to prevent confusing appearance.