One more thing about caches... oops.

- Caches in a real system

**Question:** What about instructions?

So far:

- Instruction fetch path
- Instruction cache
- Memory

**Diagram:**

- Data cache
- Data flow:
  - CPU
  - Memory
  - Instruction cache

**Text:**

- Split Inst./Data I/D
- Need to keep caches coherent
Cache coherence
Remember:

Disks:
This where all of your data stored
- files - programs - etc
- CPU can't directly access the disk
Surface holds the data

Top/bottom of platter is a surface

Head reads/writes the data

L7 6400 RPM > 15,000 RPM

Platters rotate around the spindle

Arm disk controller
Anatomy of a regular hard disk

Each track may have a different number of sectors.
Disk access time:

Seek → move the head to the right track
Rotate → wait for the right sector to come around
Transfer time → read the sector(s)

Seek → avg 3-9 ms (max 20 ms)
0.003 s
\[ \frac{1}{3} \text{ as} \]

Rotate → dependent on rotation rate
also where the data is
\[ \frac{1}{7200} \text{ RPM} \cdot \frac{1}{2} \approx 4 \text{ ms} \]

Transfer time → function of rotation rate and size of data
\[ T_{\text{access}} = T_{\text{avg seek}} + T_{\text{rotation}} + T_{\text{avg transfer}} \]

Rot. rate: 7200 RPM

Avg seek: 9 ms

Avg sectors per track: 400

For \( T_{\text{avg seek}} = \frac{1}{2} \cdot \frac{60s}{\text{min}} \cdot \frac{1000\text{ ms}}{5} \cdot \frac{1}{7200 \text{ RPM}} \)

\[ T_{\text{avg seek}} = 4 \text{ ms} \]

For \( T_{\text{avg transfer}} = \frac{60s}{7200 \text{ RPM}} \cdot \frac{1}{400 \text{ sectors/track}} \cdot \frac{1000 \text{ ms}}{5} \)

\[ T_{\text{avg transfer}} = 0.02 \text{ ms} \]

\[ T_{\text{access}} = 9 \text{ ms} + 4 \text{ ms} + 0.02 \text{ ms} \]

\[ = 13.02 \text{ ms} \]

512 B from DRAM

\(~4 \text{ ms} \]

From cache: 250 ns