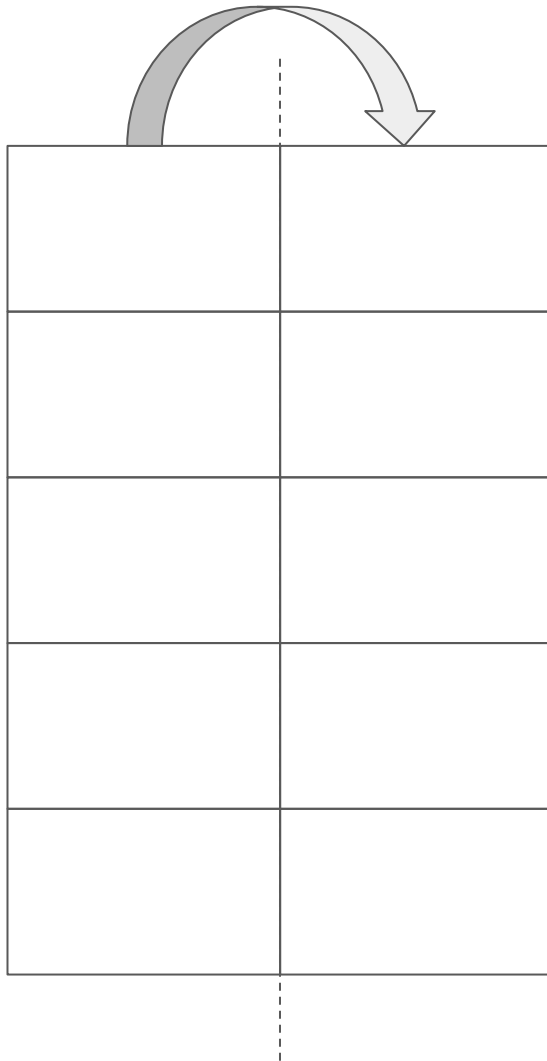


# Instructions

- Print as one page per sheet
- Fold and glue together
- Cut out individual cards



**Power of Two  
1 KB?**

$$1 \text{ KB} = 2^{10} \text{ bytes}$$

**Power of Two  
64 KB?**

$$64 \text{ KB} = 2^{16} \text{ bytes}$$

**Power of Two  
1 MB?**

$$1 \text{ MB} = 2^{20} \text{ bytes}$$

**Power of Two  
1 GB?**

$$1 \text{ GB} = 2^{30} \text{ bytes}$$

**Power of Two  
4 GB?**

$$4 \text{ GB} = 2^{32} \text{ bytes}$$

**Power of Two  
1 TB?**

**1 TB =  $2^{40}$  bytes**

**Time  
L1 Cache Reference**

**0.5 ns**

**Time  
Branch Mispredict**

**5 ns**

**Time  
L2 Cache Reference**

**7 ns  
(14x L1)**

**Time  
Mutex lock/unlock**

**100 ns**

<p><b>Time</b> <b>Main Memory Reference</b></p>	<p><b>100 ns</b> <b>(20x L2, 200x L1)</b></p>
<p><b>Time</b> <b>Compress 1 KB with Zippy</b></p>	<p><b>10,000 ns</b> <b>10 us</b></p>
<p><b>Time</b> <b>Send 1 KB over Gbit network</b></p>	<p><b>10,000 ns</b> <b>10 us</b></p>
<p><b>Time</b> <b>Read 4 KB randomly from SSD</b></p>	<p><b>150,000 ns</b> <b>150 us</b></p>
<p><b>Speed</b> <b>Round trips within same data center per second?</b></p>	<p><b>Speed</b> <b>Round trips within same data center per second?</b></p>

<p><b>Time</b> <b>Read 1 MB sequentially</b> <b>from memory</b></p>	<p><b>250,000 ns</b> <b>250 us</b></p>
<p><b>Time</b> <b>Round trip within</b> <b>same datacenter</b></p>	<p><b>500,000 ns</b> <b>500 us</b></p>
<p><b>Time</b> <b>Read 1 MB sequentially</b> <b>from SSD</b></p>	<p><b>1 ms</b> <b>(4x memory)</b></p>
<p><b>Time</b> <b>Disk seek</b></p>	<p><b>10 ms</b> <b>(20x data center roundtrip)</b></p>
<p><b>Time</b> <b>Read 1 MB sequentially</b> <b>from Gbit network</b></p>	<p><b>10 ms</b> <b>(40x memory, 10x SSD)</b></p>

<b>Time</b> <b>Read 1 MB sequentially</b> <b>from disk</b>	<b>30 ms</b> <b>(120x memory, 30x SSD)</b>
<b>Time</b> <b>Round trip CA-AMS-CA</b>	<b>150 ms</b>
<b>Power of ten?</b> <b>ns / us / ms</b>	<b>ns = 10<sup>-9</sup> s</b> <b>us = 10<sup>-6</sup> s</b> <b>ms = 10<sup>-3</sup> s</b>
<b>Speed</b> <b>Read sequentially</b> <b>from disk</b>	<b>30 MB/s</b>
<b>Speed</b> <b>Read sequentially</b> <b>from Gbit network</b>	<b>100 MB/s</b>

**Speed  
Read sequentially  
from SSD**

**1 GB/s**

**Speed  
Read sequentially  
from memory**

**4 GB/s**

**Speed  
World-wide round trips  
per second?**

**6-7 world-wide round trips  
per second**