

PROBLEMS

1. Consider the operation of a machine with the data path of Figure 2-2. Suppose that loading the ALU input registers takes 5 nsec, running the ALU takes 10 nsec, and storing the result back in the register scratchpad takes 5 nsec. What is the maximum number of MIPS this machine is capable of in the absence of pipelining?
2. What is the purpose of step 2 in the list of Sec. 2.1.2? What would happen if this step were omitted?
3. On computer 1, all instructions take 10 nsec to execute. On computer 2, they all take 5 nsec to execute. Can you say for certain that computer 2 is faster? Discuss.
4. Imagine you are designing a single-chip computer for an embedded system. The chip is going to have all its memory on chip and running at the same speed as the CPU with no access penalty. Examine each of the principles discussed in Sec. 2.1.4 and tell whether they are so important (assuming that high performance is still desired).
5. A certain computation is highly sequential—that is, each step depends on the one preceding it. Would an array processor or a pipeline processor be more appropriate for this computation? Explain.
6. To compete with the newly-invented printing press, a medieval monastery decided to mass-produce handwritten paperback books by assembling a vast number of scribes in a huge hall. The head monk would then call out the first word of the book to be produced and all the scribes would copy it down. Then the head monk would call out the second word and all the scribes would copy it down. This process was repeated until the entire book had been read aloud and copied. Which of the parallel processor systems discussed in Sec. 2.1.6 does this system resemble most closely?
7. As one goes down the five-level memory hierarchy discussed in the text, the access time increases. Make a reasonable guess about the ratio of the access time of optical disk to that of register memory. Assume that the disk is already on-line.
8. Sociologists can get three possible answers to a typical survey question such as “Do you believe in the tooth fairy?”—namely, yes, no, and no opinion. With this in mind, the Sociomagnetic Computer Company has decided to build a computer to process survey data. This computer has a trinary memory—that is, each byte (tryte?) consists of 8 trits, with a trit holding a 0, 1, or 2. How many trits are needed to hold a 6-bit number? Give an expression for the number of trits needed to hold n bits.
9. Compute the data rate of the human eye using the following information. The visual field consists of about 10^6 elements (pixels). Each pixel can be reduced to a superposition of the three primary colors, each of which has 64 intensities. The time resolution is 100 msec.
10. Compute the data rate of the human ear from the following information. People can hear frequencies up to 22 kHz. To capture all the information in a sound signal at 22 kHz, it is necessary to sample the sound at twice that frequency, that is, at 44 kHz. A 16-bit sample is probably enough to capture most of the auditory information (i.e., the ear cannot distinguish more than 65,535 intensity levels).

11. Genetic information in all living things is coded as DNA molecules. A DNA molecule is a linear sequence of the four basic nucleotides: *A*, *C*, *G*, and *T*. The human genome contains approximately 3×10^9 nucleotides in the form of about 30,000 genes. What is the total information capacity (in bits) of the human genome? What is the maximum information capacity (in bits) of the average gene?
12. A certain computer can be equipped with 268,435,456 bytes of memory. Why would a manufacturer choose such a peculiar number, instead of an easy-to-remember number like 250,000,000?
13. Devise a 7-bit even-parity Hamming code for the digits 0 to 9.
14. Devise a code for the digits 0 to 9 whose Hamming distance is 2.
15. In a Hamming code, some bits are “wasted” in the sense that they are used for checking and not information. What is the percentage of wasted bits for messages whose total length (data + check bits) is $2^n - 1$? Evaluate this expression numerically for values of n from 3 to 10.
16. The disk illustrated in Figure 2-19 has 1024 sectors/track and a rotation rate of 7200 RPM. What is the sustained transfer rate of the disk over one track?
17. A computer has a bus with a 5 nsec cycle time, during which it can read or write a 32-bit word from memory. The computer has an Ultra4-SCSI disk that uses the bus and runs at 160 Mbytes/sec. The CPU normally fetches and executes one 32-bit instruction every 1 nsec. How much does the disk slow down the CPU?
18. Imagine you are writing the disk management part of an operating system. Logically, you represent the disk as a sequence of blocks, from 0 on the inside to some maximum on the outside. As files are created, you have to allocate free sectors. You could do it from the outside in or the inside out. Does it matter which strategy you choose? Explain your answer.
19. How long does it take to read a disk with 10,000 cylinders, each containing four tracks of 2048 sectors? First, all the sectors of track 0 are to be read starting at sector 0, then all the sectors of track 1 starting at sector 0, and so on. The rotation time is 10 msec, and a seek takes 1 msec between adjacent cylinders and 20 msec for the worst case. Switching between tracks of a cylinder can be done instantaneously.
20. RAID level 3 is able to correct single-bit errors using only one parity drive. What is the point of RAID level 2? After all, it also can only correct one error and takes more drives to do so.
21. What is the exact data capacity (in bytes) of a mode 2 CD-ROM containing the now-standard 80-min media? What is the capacity for user data in mode 1?
22. To burn a CD-R, the laser must pulse on and off at a high speed. When running at 10x speed in mode 1, what is the pulse length, in nanoseconds?
23. To be able to fit 133 minutes worth of video on a single-sided single-layer DVD, a fair amount of compression is required. Calculate the compression factor required. Assume that 3.5 GB of space is available for the video track, that the image resolution is 720×480 pixels with 24-bit color, and images are displayed at 30 frames/sec.

24. Blu-Ray runs at 4.5 MB/sec and has a capacity of 25 GB. How long does it take to read the entire disk?
25. The transfer rate between a CPU and its associated memory is orders of magnitude higher than the mechanical I/O transfer rate. How can this imbalance cause inefficiencies? How can it be alleviated?
26. A manufacturer advertises that its color bit-map terminal can display 2^{24} different colors. Yet the hardware only has 1 byte for each pixel. How can this be done?
27. A bit-map terminal has a 1600×1200 display. The display is redrawn 75 times a second. How long is the pulse corresponding to one pixel?
28. In a certain font, a monochrome laser printer can print 50 lines of 80 characters per page. The average character occupies a box $2 \text{ mm} \times 2 \text{ mm}$, about 25% of which is toner. The rest is blank. The toner layer is 25 microns thick. The printer's toner cartridge measures $25 \times 8 \times 2 \text{ cm}$. How many pages is one toner cartridge good for?
29. When odd-parity ASCII text is transmitted asynchronously at a rate of 5600 characters/sec over a 56,000 bps modem, what percent of the received bits actually contain data (as opposed to overhead)?
30. The Hi-Fi Modem Company has just designed a new frequency-modulation modem that uses 64 frequencies instead of just 2. Each second is divided into n equal time intervals, each of which contains one of the 64 possible tones. How many bits per second can this modem transmit, using synchronous transmission?
31. An Internet user has subscribed to a 2 Mbps ADSL service. Her neighbor has subscribed to a cable Internet service that has a shared bandwidth of 12 MHz. The modulation scheme in use is QAM-64. There are n houses on the cable, each with one computer. A fraction f of these computers are online at any one time. Under what conditions will the cable user get better service than the ADSL user?
32. A digital camera has a resolution of 3000×2000 pixels, with 3 bytes/pixel for RGB color. The manufacturer of the camera wants to be able to write a JPEG image at a $5x$ compression factor to the flash memory in 2 sec. What data rate is required?
33. A high-end digital camera has a sensor with 16 million pixels, each with 3 bytes/pixel. How many pictures can be stored on a 1-GB flash memory card if the compression factor is $5x$? Assume that 1 GB means 2^{30} bytes.
34. Estimate how many characters, including spaces, a typical computer science textbook contains. How many bits are needed to encode a book in ASCII with parity? How many CD-ROMs are needed to store a computer science library of 10,000 books? How many double-side, dual-layer DVDs are needed for the same library?
35. Write a procedure *hamming(ascii, encoded)* that converts the low-order 7 bits of *ascii* into an 11-bit integer codeword stored in *encoded*.
36. Write a function *distance(code, n, k)* that takes an array *code* of n characters of k bits each as input, and returns the distance of the character set as output.