Problem set 2

Graded out of 52. There was more spread this time than in the first assignment, a combination of me being a bit more strict, and some questions requiring clearly correct answers.

Numeric precision of answers clearly remains a fuzzy concept. I did deduct a few points for grossly excessive precision. For example, since we don't know how long it takes to drive across the US to more than a couple of digits, you shouldn't have more than that in your data transfer rate.

A number of people are confused on the roles of bits and bytes in questions that ask how many bits are needed to store some kind of number. Please be sure you understand why you got this wrong if you did, since it's absolutely fundamental.

Watch out for units like bits and bytes; there's a factor of 8 there. Similarly, watch out for factors of 10 that go wrong if you get the conversion between say GB and TB wrong. There were a fair number of places where people forgot factors of 10 or 100, or failed to convert bytes to bits.

As always, if my answers don't make sense, please ask. On exceptionally rare occasions I have been known to screw up completely.

Problem 1: [total: 28 pts, 4 each]

(a) 16 pts, 4 each

(i) Hours to send 100 PB at 100 Gbps?
100 PB is $100 \times 10^{15} \times 8$ bits
transfer rate of 100 Gbps is $100 \times 10^9$ bits/sec
dividing gives $8 \times 10^6$ seconds or about 2200 hours (nearly 100 days!).

I marked (but didn’t penalize) answers like 2222 hours, which result from division without thinking about precision.

(ii) Transfer rate for sending 100 PB from San Francisco to NYC by truck?

2500 miles at 60 mph is about 40 hours (less than 2 days if non-stop).
$100 \times 10^{15} \times 8 / (40 \times 60 \times 60) / 10^9$ is about 5500 Gbps. The specific travel time doesn’t matter as long as it’s sort of sensible. I did penalize excess precision here, however, since the time to drive across the country is clearly imprecise.

A number of people didn’t answer the question about transfer rate because they got caught up in the interesting by-way about how many disks would fit in a truck. (I think that one truck would be enough, but your mileage or truckage might vary.)

(iii) How many DVDs for 100 PB?

$100 \times 10^{15}$ PB / $5 \times 10^9$ GB in a DVD = $20 \times 10^6$, or 20 million.

(iv) How high is the stack of DVDs in meters?

$20 \times 10^6$ DVDs * $1.2 \times 10^{-3}$ meters each = $24 \times 10^3$ = 24,000.

(b) [8 pts, 4 each]

Cost per MB and weight in grams per MB...

1980 device:

$120,000$ for 1 GB so $120$/MB
$250$ kg for 1 GB so $250$ gm for 1 MB

2021 device:

1 TB is $10^6$ MB
$20$ for $10^6$ MB, so $20 \times 10^-6$ / MB (fractions of a cent would be ok here)
$25$ gm for $10^6$ MB so $25 \times 10^-6$ gm / MB.

I asked for scientific notation, and people were remarkably good at providing it. In retrospect, it was probably more of a hindrance than a help in this specific problem, though in general it’s a good idea.
(c) [4 pts]

Throughput of avian carriers in Mbps?

$10^6 \times 8 \text{ Mbits in 2 hours is } 10^6 \times 8 / 2 / 3600$, or about 1,100 Mbps.
Excess precision noted but not penalized.

Problem 2: [8 pts: 4 + 4]

(a) How thick with the folded map be, in meters?

$0.1 \text{ mm} \times 2^{25}$ is $0.1 \times 30 \times 10^6$, so about $3 \times 10^6 \text{ mm}$ or 3,000 meters.
The 0.1 mm thickness is an estimate itself, so giving answers to 3 or 4 digits of precision is uncalled for.

(b) Is 0.1mm right for paper thickness, and why?

Very close. A standard ream of paper is 500 sheets and is about 2 inches = 5 cm = 50 mm thick. I was looking for some concrete reason (like a ream of paper or an actual measurement or an estimate derived from a physical pile of paper), not just “it feels right.”

Problem 3: [16 pts: 8 + 8]

(a) [8 pts: 4 + 2 + 2]

(i) How many bits for a unique id for each US car, and why?

300 million cars (1 per person) is a decent estimate for the US.
300 million is $300 \times 10^6 \approx 2^9 \times 2^{20}$ so 29 bits. 27 or 28 would be ok too.

(ii) How many bytes for this number?

4. round up

(iii) How many bytes if we add Canadian cars?

4. There are only about 35M Canadians, so there’s no effect on the number of bytes.

Generally well done, but some people were badly confused about how bits and bytes relate to this problem. Please check your understanding, and ask if you remain uncertain about what’s going on.
(b) [8 pts: 4 + 4]

(i) What range of digits can you make on your fingers and thumbs?

0 to 1023 (exactly). There is an exact answer here that I was looking for. I probably confused people by asking for approximations when the input data is uncertain, but there is no uncertainty here. And the range is $0 \ldots 2^n - 1$; the upper value does not include $2^n$.

(ii) What range if you can also use toes?

0 to $2^{20} - 1$. The exact decimal value is 1,048,575, but the expression is easier and totally acceptable.