Instructions: Solve all problems to the best of your ability. You are encouraged to work with other students in the class, but you must write your own understanding of the solutions (and cite any outside resources you use). Note that you should provide solutions, not just answers—that means you are explaining how you solved the problem. Upload solutions to Showbie before our first class meeting. If you get stuck, send questions to me at nreden@bancroftschoool.org.

1. A 3.0 GHz computer microprocessor does $3.0 \cdot 10^9$ computations per second. How far does light (which has a speed of $c = 2.99792458 \cdot 10^8$ m/s) travel in the time it takes this processor to do one computation?

2. Water has a density of $1$ g/cm$^3$. What is the mass of a cubic meter of water? What about a cubic meter of gold ($19.3$ g/cm$^3$)?

3. A furlong is a unit of length equal to $\frac{1}{8}$ of a mile. A fortnight is 14 days. Express the speed of light in furlongs per fortnight. Also find it in feet per nanosecond. Show your work.

4. With a wooden ruler, you measure the length of a rectangular piece of sheet metal to be 12 mm. With micrometer calipers, you measure the width of the rectangle to be 5.98 mm. Use the correct number of significant figures when finding (a) the area of the rectangle, (b) the ratio of the rectangle’s width to its length, (c) the perimeter of the rectangle, (d) the difference between the length and the width, and (e) the ratio of the length to the width.

5. How many times does a human heart beat during a person’s lifetime? How many gallons of blood does it pump? (Estimate that the heart pumps $50$ cm$^3$ of blood with each beat, along with any other relevant quantities.)

6. High-energy physicists sometimes use Planck units, which are constructed from fundamental constants. (They are also called “natural units” for this reason.) Use dimensional analysis to find the Planck length $l_P$, a combination of fundamental constants with dimensions of length, in meters. Fundamental constants include the speed of light $c$, the gravitational constant $G = 6.674 \cdot 10^{-11}$ m$^3$ kg$^{-1}$ s$^{-2}$, and Planck’s constant $\hbar = 1.055 \cdot 10^{-34}$ kg m$^2$/s. ($l_P$ is the length scale at which relativity, gravity, and quantum mechanics are all equally important. Roughly speaking, a photon with wavelength around $l_P$ would collapse into a black hole. Fundamental physics is not well-understood at this scale.)

7. You are doing an experiment to determine the density of an unknown block of material. First you find its mass to be $1.327 \pm 0.003$ kg. Then you immerse it in water and, by measuring the water level rise, find that its volume is $8.5 \pm 0.5$ cm$^3$. What is its density? Include a calculated uncertainty.
8. A star emits light equally in all directions. This light is a form of energy, which flows out at a constant rate. That means the energy emitted by the star at a particular moment in time takes the form of a spherical shell that expands outward. The **intensity** of the light at some distance from the star is defined as the rate at which energy passes through that distance per unit area. How does intensity scale with distance from the star?