2009 01 20

16722 homework due today

(1) crash of the "gimli glider"

The article demonstrates the dangers inherent in ambiguous conversion between different measuring systems. The mechanic provided a conversion factor of "1.77" but did not state the units: pounds-per-liter (of fuel) [This is already a crazy situation, as it mixes English units, pounds, for mass (or weight, ambiguously) with metric units, liters, for volume.] The pilot misinterpreted this number to mean kilograms-per-liter. They therefore added the correct <u>number</u> of pounds of fuel instead of the required <u>same number</u> of kilograms of fuel ... less than half of what was required! By the way, it was very foolish of the pilot not to catch the error, as he should have known that one liter of any "everyday" liquid is approximately 1 kg; 1.77 kg/liter of <u>anything</u> is unusually dense.

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(2) Show that your body's power demand, about 2000 calories (i.e., food calories) per day is about the same as a 100 watt light bulb.

$$2000 \frac{\cancel{\text{food. calories}}}{\text{day}} \times \frac{1000 \text{ calories}}{\cancel{\text{food. calorie}}} \times 4.2 \frac{\text{joule}}{\text{calorie}}$$

$$\times \frac{1 \text{ day}}{24 \text{ hour}} \times \frac{1 \text{ hour}}{60 \text{ minute}} \times \frac{1 \text{ minute}}{60 \text{ second}}$$

$$= 97 \frac{\text{joule}}{\text{second}} \approx 100 \text{ watt}$$

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(3) Compare your metabolism to the sun's.

$$\text{my-metabolism} \approx \frac{100 \text{ watt}}{75 \text{ kg}} \approx 1.3 \frac{\text{watt}}{\text{kg}}$$

$$^{*}\text{sun's\_metabolism} \approx \frac{3.8 \times 10^{26} \text{ watt}}{2 \times 10^{30} \text{ kg}} \approx 1.9 \times 10^{-4} \frac{\text{watt}}{\text{kg}}$$

* http://scienceworld.wolfram.com/astronomy/Sun.html

So my metabolism is nearly 10,000 times greater than the sun's! [The sun's metabolism is comparable to a pile of rotting leaves.]

It is at first surprising, because the sun is so hot, but its surface-to-volume ratio ($\sim$ 1/linear-dimension) is very much smaller than mine, so it loses heat much more slowly than I do; a very small heat production rate in an enormous volume with a relatively small surface area for it to escape accounts for its high surface temperature.

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(4) compare energy density in candy bar, gasoline, and typical batteries

(from previous slides)

candy bar: $\text{energy-density\_CB} \approx \dfrac{170 \text{ food.calories}}{10\,\text{gm.fat} + 20\,\text{gm.carbs}}$

$$\approx \frac{170}{30} \frac{\cancel{\text{food}}.\text{calories}}{\text{gm}} \times \frac{1000 \text{ calories}}{\cancel{\text{food}}.\text{calorie}} \times 4.2 \frac{\text{joule}}{\text{calorie}}$$

$$\approx 24 \text{ kJ/gm}$$

gasoline: (from Wikipedia entry "gasoline")

$$\approx 45 \frac{\text{MJ}}{\text{kg}} \times \frac{1000 \text{ kJ}}{\text{MJ}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \approx 45 \text{ kJ/gm}$$

batteries: (from Fraden, 3rd Ed, App. Table A.22, p573)

$$\approx 90 \frac{\text{watt.hr}}{\text{kg}} \times \frac{3600 \text{ second}}{\text{hr}} \times \frac{1 \text{ kg}}{1000 \text{ gm}} \times \frac{1 \text{ joule}}{\text{watt.second}}$$

$$\approx 300 \frac{\text{joule}}{\text{gm}} \times \frac{1 \text{ kJ}}{\text{J}} \approx 0.3 \frac{\text{kJ}}{\text{gm}}$$

So gasoline packs $\approx$ twice the energy density of a candy bar, and that is $\approx$ 150 times the energy density in a typical battery! Conclusions: feed your robots candy bars, not batteries!

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(5) For a scene illuminated in Pittsburgh sunlight, estimate the <u>energy</u> delivered to a CCD pixel in 1msecond exposure.

"insolation" $\approx 4 \frac{kWh}{m^2 \cdot day}$ here (see Wikipedia)

$$\approx 4 \frac{kW}{m^2} \frac{hour}{day} \times \frac{1\ day}{24hr} \times \frac{1\ joule}{W \cdot second} \times \frac{1000}{k}$$

$$\approx 200 \frac{joule}{second \cdot m^2}$$

average scene reflectance $\approx$ 15%

(numbers in range 10-20% found in surveying web references; Kodak says 18%)

So expect $\approx 30 \frac{joule}{m^2 \cdot second}$ leaving the scene.

From slide 32, the power density at the sensor is

$$P_D = \frac{\pi}{4} P_S \underbrace{\cos^4 \theta_{CD}}_{1 \text{ on axis}} / \underbrace{f\text{-number}^2}_{}$$

close to 1 — typically 11 in sunlight

$$\approx 30 \frac{joule}{m^2 \cdot second} \frac{1}{120} \approx 0.25 \frac{joule}{m^2 \cdot sec}$$

Typical pixel $\approx (10 \mu m)^2 \approx 10^{-10} m^2$

So energy reaching pixel in 1 millisecond

$$\approx 0.25 \frac{joule}{m^2 \cdot second} \times 10^{-10} m^2 \times 10^{-3} second \approx 2.5 \times 10^{-14} J$$

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(6) head & shoulders photo :- see attached

(7) making reasonable assumptions about camera dimensions etc, shade the photo as $\cos^4 \theta_{LS}$:

see attached