Problem 1 Taking a hot shower on a sailboat

A friend of mine recently told me that his sailboat carries a 26 gallon (nearly 100 l) freshwater tank. The tank is located against the hull, in close contact with the cold waters of the Gulf of Maine. Thus the water in the freshwater tank stays around 65 degrees F, or about 18 C.

He wanted to know whether it would be practical to withdraw a small amount of water from the tank, heat it on the propane stove in the galley and pour it into the freshwater tank to raise the water in the tank to a temperature that would make quick showers less unpleasant.

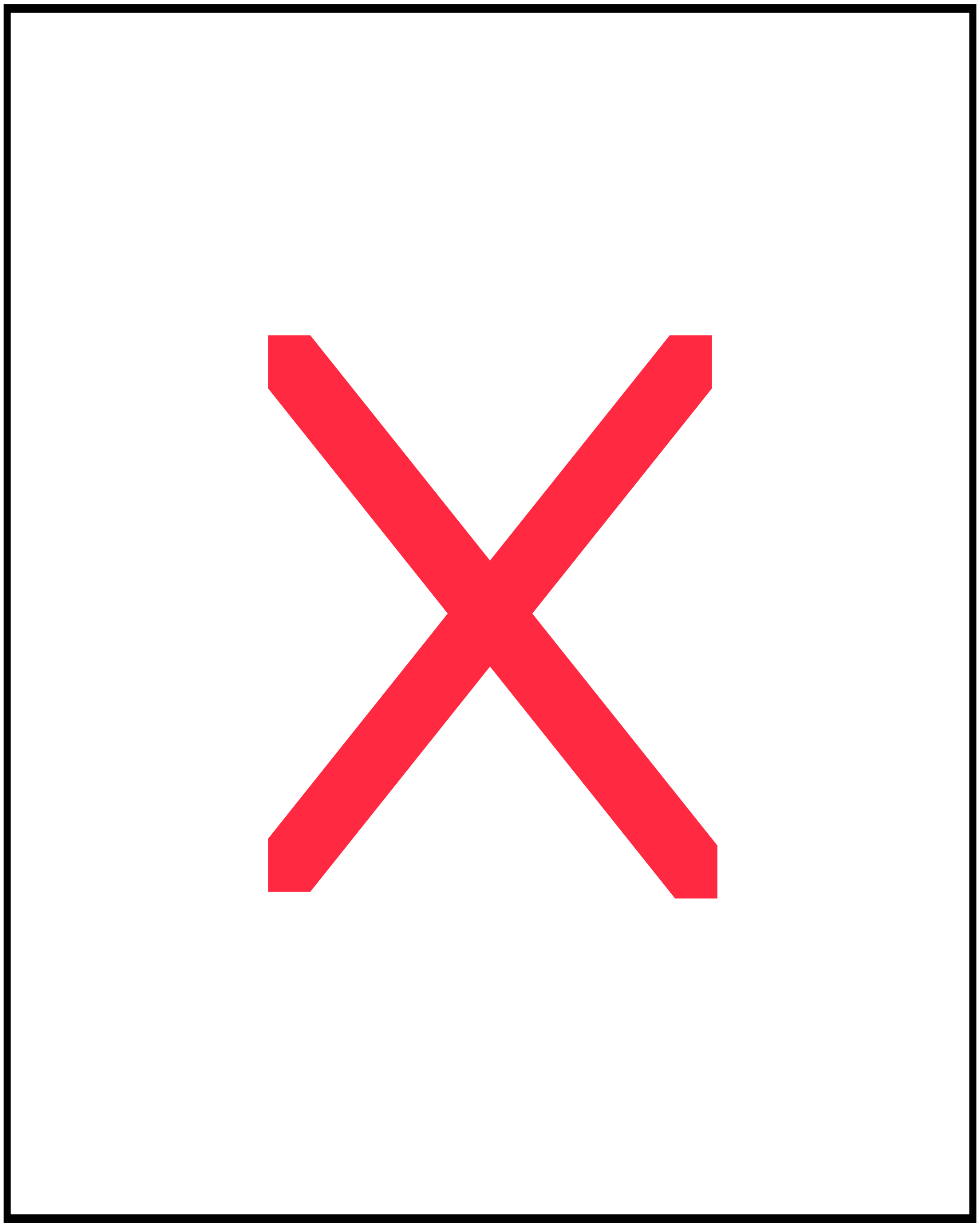
(1) How much energy is required to raise the water in the tank by one °C?
(2) How much energy would be required to raise the water temperature in the tank to 25 °C?
(3) How much energy would be required to raise the temperature of the water to comfortable bath temperature of about 40 °C?
(4) Assume the only way to heat that water is by taking 2 liters of water out of the tank, heating it in a pot to boiling, and pouring it back into the tank What will the temperature of the water be after one such heating cycle?
(5) Many sailboats are equipped with simple solar showers. During daylight hours in the summer in Maine, approximately 600 cal cm^{-2} day^{-1} strikes the surface of the earth. How long would it take to heat up 20 l of water to 40 °C for a shower? (you will have to make some sort of an assumption about the distribution of solar radiation over the course of the day).
(6) What do you think? Is it practical to heat up small amounts of water and pour it back into the water tank to provide hot water, or not?

Mean Total Solar Energy Flux
Estimated for the 15th day of each year
(From Hutchinson 1957, A Treatise on Limnology. Volume 1, p 371)

	$cal/cm^2/day$
January	152
February	245
March	367
April	495
May	582
June	625
July	605
August	537
September	415
October	285
November	180
December	130

Problem 2 Global Population

The Following Data on World Human Populations are from the U.S. Bureau of the Census web page. Numbers prior to 1950 are rough estimates; data from 1950 to 2002 are more robust. Figures for years subsequent to 2002 are U.S. Census projections.



Human populations are often modeled as growing according to an exponential growth model. That means that human population grows according to the equation

$$N(t) = N(0)e^{rt}$$

where N is the population at time t (measured in years), e is the base of natural logarithms, and r is the growth rate of the population.

(1) What was the approximate growth rate of the global human population for each of the following time periods:
   a. Pre industrial revolution (10,000 BCE to 1700)
   b. Industrial revolution (1700-1850)
   c. Early Modern Era (1850-1900)
   d. Early 20th Century (1900-1950)
   e. Modern Era (1950-2000)

(2) What is the effective growth rate projected by the U.S. Census bureau for the period from 2000 to 2050?

(3) What patterns, if any, do you see in these numbers?

(4) Does this explicit comparison of historic growth rates with projected growth rates give you more or less confidence in the projections? What factors do you think account for the differences between recent growth rates and the growth rates being projected for the next 50 years?

Problem 3 Intestinal Stocks and Flows

Last year, that fount of numerical precision, the Bates Daily included the following numerical tidbit in "Digitz" column:

> 5-10 pounds. Amount of rotting dead meat in the intestines of meat eaters at any given time.

(1) Using your back-of-the-envelope thinking skills and what you now know about the relationship between stocks, flows, and residence times, do you think this figure appears credible? Why or why not?

> (Hint: Construct a stock and flow model of food in your intestine. Estimate flows – inputs and out puts – and turnover times based on personal experience, and calculate the size of stocks that would reasonably account for those turnover times).

Problem 4 Estimation and Statistics

Students often wonder when preparing technical graphs and figures with "error bars" whether it is more useful to show the standard deviation or the standard error. Actually, the choice depends on what you want to communicate with the error bars.

(1) What is the difference between a STANDARD DEVIATION and a STANDARD ERROR of a mean?

(2) Assuming that the purpose of the error bar is to give viewers of the graph a way to estimate the range of values one might reasonably expect to see when taking a single measurement, which would be more useful?

(3) Assuming that the purpose of the error bars is to give viewers of the graph a way to estimate the range of averages one might reasonably expect to see when taking as many measurements are were used in your study, which would be more useful?

Problem 5 Question from Mt. David Lab

(1) A group of students set out to measure the snow pack on Mount David. They collect 200 snow depths, from randomly selected locations on the mountain. Their measurements of snow depth had an average of 15.3 cm, with a standard deviation of 9.4 cm. They take just a single measurement of snow density from a point located at the summit of Mount David, reasoning that since the summit is centrally located, that sample should be representative of conditions across the whole area. The sample has a (volumetric) snow density of 0.38 g/cm^3.
   a. Assuming that Mount David has an area of 35,000 square meters, how much water is stored on Mount David, according to this group's data?
   b. What is the standard error of that estimate?
   c. Comment briefly on the methods they used. Is there anything they have done that might significantly bias their results? If so, what would you suggest they do differently next year?

Problem 6 Home Energy Audits

A common feature of home energy audits is the use of simple infrared cameras to take a picture of the house being studied.

(1) Given what you know about thermal radiation, why are infrared camaras so helpful for home energy audits?
(2) How would you analyze a home energy audit infrared image taken on a cold day in the winter? On a hot day in the summer?