very helpfully explains how he himself has used it. It can also be used for a self-paced/self-study course on the subject and is certainly a useful book to have for reference. The reader using the Omnibook for self-study would no doubt wish for more references, for these are not given in any complete and systematic way. I would have liked to have seen Levenspiel's presentation of the dynamics of reactors, for his virtuosity in the integration of text and figure would have been extended by a description of the recent work on possible behaviors of the stirred tank. But I must not get carried away on my hobby horses.

The last chapter (sec. 100) is an admirable collection of units and conversions between them. I trust I shall never need to use a number with a dimension, but if such disaster should come upon me, I shall flee for refuge to this "Miscellany". As in so many places throughout the book, Levenspiel has here an original touch; he gives "spectra" of the orders of magnitude of various diffusivities, conductivities and rates of reaction. □

## ChE class and home problems

*The object of this column is to enhance our readers' collection of interesting and novel problems in Chemical Engineering. Problems of the type that can be used to motivate the student by presenting a particular principle in class or in a new light or that can be assigned as a novel home problem are requested as well as those that are more traditional in nature that elucidate difficult concepts. Please submit them to Professor H. Scott Fogler, ChE Department, University of Michigan, Ann Arbor, MI 48109.*

**Our undergraduate student readers are encouraged to submit their solution to the following problem to Prof. Ray Fahien, Editor, CEE, ChE Department, University of Florida, Gainesville, FL 32611, before January 1, 1982. A complimentary subscription to CEE will be awarded, to begin immediately or, if preferred, after graduation, for the best solution submitted (Oregon State students are not eligible). We will publish Prof. Levenspiel's solution in a subsequent issue.**

# DOLPHIN PROBLEM

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Whales, dolphins and porpoises are able to maintain surprisingly high body temperatures even though they are immersed continuously in cold, cold water. Since the extremities of these animals (tails, fins, flukes) have a large surface to volume ratio, a large portion of the heat loss occurs there.

a) Now an ordinary engineering junior designing a dolphin from first principles might view the flipper as a flat single pass heat exchanger with heat transfer occuring between a blood vessel passing through the flipper and the flipper itself which is assumed to be at the water ambient temperature.

Let us suppose that blood at 40°C enters the flipper at 0.3 kg/s, feeds the flipper, is cooled somewhat, and then returns to the main part of the body. The dolphin swims in 4°C water, the overall heat transfer coefficient is 100 cal/s·m²·K and the heat transfer area is 3 m². At what temperature does the blood reenter the main part of the body of the dolphin?

b) Frankly, the ordinary engineer above (which you obviously are not) would design a lousy dolphin. Let's try to do better; in fact let us try to learn from nature. Let us see if we can reduce some of the undesirable heat loss by inserting an internal heat exchanger B ahead of the flipper exchanger A above. This internal exchanger is a countercurrent one which transfers heat from the outgoing warm arterial blood to the cooled venous blood returning from the flipper. Heat conservation of this sort, by having arteries and veins closely paralleling each other, in counterflow, is one of nature's clever tricks.

Assume for this internal exchanger B that

$$A_B = 2\ m^2$$

and

$$U_B = 150\ cal/s{\cdot}m^2{\cdot}K$$

With this extra exchanger find $T_3$, the temperature of blood returning to the main part of the body; and, in addition, the fraction of original heat loss which is saved. Approximate the properties of blood by water. □