NOTE

Physics and Pharmacy: More Than "Ph"

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In most colleges and universities, algebra- and calculus-based physics are required courses taken by students in a wide variety of academic majors, including the physical, biological, and health sciences and engineering. It is necessary (and fun!) to include examples from these areas to convey to the diverse student body how applicable physics is in their respective fields. In some cases where the population of a certain section is dominated by students in a particular major, instructors are challenged to make the course relevant and interesting, while covering the major themes of physics. Such is the case at the St. Louis College of Pharmacy, where all students are pharmacy majors. The five-year B.S. degree places significant emphasis on chemistry and biology. Students often ask why they have to take physics (math and liberal arts, too). My goal is to try to answer the question, "What do physics and pharmacy have in common?"

I cover the usual topics of physics, but I try to present plenty of examples dealing with the human body. Pharmacy students are interested in things like baseball and cars, so I spend a few weeks on mechanics to introduce concepts such as units, motion, velocity, vectors, force, and energy. Rotational motion includes a discussion of torques, levers, and how muscles and bones provide the necessary forces for motion. Topics in waves and vibrations include sound and the ear, as well as ultrasound and the Doppler effect. Devices such as defibrillators and pacemakers are discussed when covering electricity and magnetism. When studying optics, students get to play "optometrist" for the day. Nuclear decay is important for their understanding of nuclear medicine and the use of radiation in organ imaging and cancer treatment.

An important topic for pharmacy students is fluid statics and dynamics. Concepts such as pressure, pressure variation with depth, Pascal's principle, flow rate, viscosity, and Poiseuille's law give students necessary background to understand the effects of blood pressure, transport mechanisms, and cholesterol deposits.

An example that the students go over carefully is one in which a patient is to be given a blood transfusion. The blood is to flow from a bag suspended above a needle inserted into a vein in the arm. The purpose of raising the bag is to provide a large enough pressure across the length of the needle to force the blood through it.

We consider two major concepts to solve this problem—pressure variation with depth and Poiseuille's law. The variation of pressure with depth is given by $p = \rho g h$, where p is the pressure at a distance h below the top of a fluid having a mass density ρ, and g is the gravitational field strength. Poiseuille's law relates volume flow rate of a fluid to several other parameters and can be written

$$Q = \frac{\pi r^4 \Delta p}{8 \eta L}$$

where Q is the volume flow rate expressed as $\Delta V/\Delta t$, where V is volume and t is time, r is the radius of the needle, Δp is the pressure difference between ends of the needle, h is the viscosity of blood, and L is the length of the needle.

Now suppose we wish to deliver 500 cc (5×10^{-4} m^3) of blood in 200 s using a needle that is 5.0 cm long and 1.0 mm in diameter. The viscosity of whole blood at body temperature (37 °C) is about 1.7×10^{-3} poiseuille (Pl), and the density is about 1.05 g/cc (1050 kg/m^3). This information yields a value for the flow rate of $Q = 2.5 \times 10^{-6}$ m^3/s and requires a pressure difference of Δp = 8700 Pa (65 mmHg) across the needle.

As a first approximation, we take the pressure at the inlet of the needle to be 8700 Pa and at the outlet (in the arm) to be 0 Pa. To obtain this pressure difference, the bag should be placed at a height of 0.85 m above the needle.

At this point, however, we discuss the blood pressure in various blood vessels of the circulation system.[1] The "normal" blood pressure of 120/80 mmHg occurs near the aorta and decreases throughout the system to 0 mmHg in the right atrium. The mean blood pressure decreases as blood flows from the aorta, to the arteries, to the arterioles, and then to the capillaries. After leaving the capillaries, blood flows to the veins, to the venules, and then to the largest veins—the venae cavae, which carry blood directly to the heart. The pressure in the smaller veins ranges from about 10 to 20 mmHg (1300 to 2700 Pa).

If we take the pressure at the outlet of the needle (in the arm) to be 2700 Pa, then at the inlet, the pressure must be 11,400 Pa. We find that the bag should be placed 1.1 m above the arm.

Variations on the problem include differences in needle sizes (length, diameter), fluids (plasma, glucose, medications), flow rates (volume, time), and positions of the patient (standing, sitting, lying down). In the example given, we excluded any flow problems that may occur in the tube from the bag to the needle, as well as problems associated with turbulence or Bernoulli effects.

This example shows how to use a variety of physics concepts in a problem that is quite applicable to the pharmacy student. Many of these same examples would be appropriate for sections dominated by pre-medical, nursing, and various therapy (physical, occupational, respiratory, etc.) students. Using relevant examples of applications of physics with students in most areas of study helps to promote student interest and learning.

Reference

1. Elaine N. Marieb, *Human Anatomy and Physiology*, 2nd ed. (Benjamin/Cummings, Redwood City, CA, 1992), pp. 640–641.

et cetera...

Do Cathedral Glasses Flow?

In an earlier piece, I quoted a person who suggested that glass of stained glass windows in medieval cathedrals had flowed and the panes were now thicker at the bottom than at the top.[1] A definitive article on this subject has appeared that indicates that the earlier quotation was wrong.[2] I apologize for presenting the earlier incorrect piece.

"The conclusion is that window glasses may flow at ambient temperature only over incredibly long times, which exceed the limits of human history."

"As a result of the previous discussions, it can be concluded that medieval and contemporary window glasses cannot flow at room temperature in human time scales."

1. A. A. Bartlett, "et cetera," *Phys. Teach.* **33**, 535 (Nov. 1995).
2. E. D. Zanotto, *Am. J. Phys.* **66**, 392-395 (May 1998).

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