A Light Introduction to PBL

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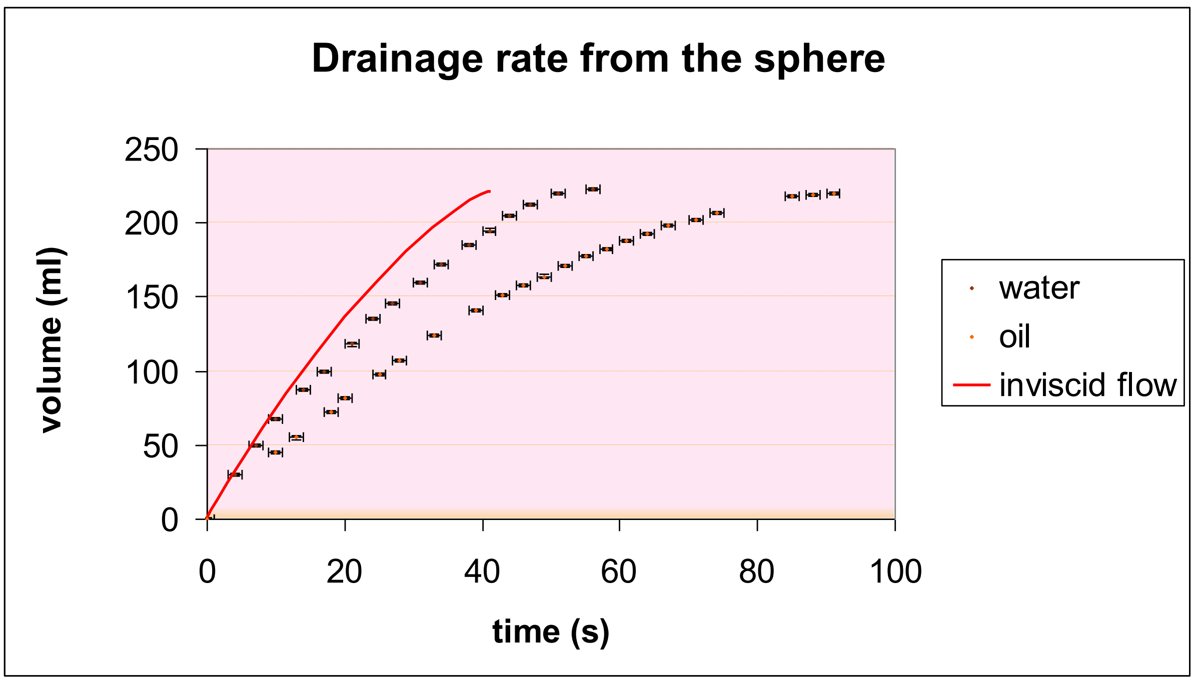
A wonderful sense of the excitement of PBL is conveyed by Ed Purcell in his article New Practical Physics (Purcell 1997 Am. J. Phys **65** (8)). Purcell organized his seminar group students into small groups of two or three and posed them a stimulating problem such as: 'Is there turbulence in the cardiovascular system?' The rules of the game were that the students were to use what they knew, had to try and work out anything they needed, but were directed not to look things up. Purcell saw this as a way of widening their physics education to tackle problems of astrophysics, geophysics or engineering, areas of applied physics that they would otherwise be unaware of. A not dissimilar group is also described in Alan Lightman's engaging novel 'Good Benito' (Lightman 1995 Good Benito Bloomsbury Publishing Ltd.). In both cases, however, it is clear that the students are from a traditional fast stream. One of the benefits of PBL however is that it often reveals important qualities in students – latent talents that might otherwise remain hidden and unacknowledged in a course with traditional assessment. Perhaps the lesson to take from Purcell and Lightman is the joy of just thinking up a problem and then giving it your best shot with limited resource, be it in the lab or classroom. Light PBL is a way to get a taste of the stimulation of PBL courses without needing to plan a whole course based around it. Many practicing physics teachers have such elements in their courses; we will discuss here some examples where the use of a simple experiment enhances the student's intuition in tackling a challenging problem. Sometimes too, we have to forgo the instinct to pose problems too precisely. Easier as these are to assess, they ask less of a student than more open-ended problems in which the students must decide on the line of attack. Consider an example that would perhaps fit nicely into a Level 1 course: a wax mould for a candle is filled with water and then allowed to drain. How long will this take? To set this in context, we usually mention the water clocks that were employed in ancient Athenian Law Courts because the ultimate goal of the exercise is to calculate the shape of the draining bowl of water that gives rise to a constant rate of fall of the water surface. This design allowed the lawyers to readily assess the length of time they had to make their points. The first part of the problem is to ask the students to make their best estimate of the draining time from the mould. The idea is to rely on intuition rather than any 'quick & dirty' estimate. The water in the mould is then drained into a cylinder and the fluid level filmed – either a digital video camera or a series of digital stills allows the drainage rate to be easily measured. Now the students can be let free on the calculation of the expected drainage rate. This involves modifying the standard treatment of draining water from a cylinder familiar from most fluid texts. Understanding how to make this modification and seeing it in practice will be the basis from which the students work out the water clock problem. The important point is that direct observation of the water level in this case and the calculation that follows give the student the pleasure of a direct comparison between a simple experiment and a piece of theory they have worked out for themselves to explain it. The students can decide how to correct for the 'flat top' caused by the large hole in the upper hemisphere of the sphere, or investigate different-sized drainage holes or different fluids. The graphs are rather instructive and can lead to interesting discussions on the effect of viscosity on the flow rate and the way this dependence changes as drainage proceeds.



Another nice example is the following. Where should dust gather in a space ship? If this problem is set in this spare form, students may make little progress. So we preface the problem with another simple experiment. An acrylic sphere is part-filled with water and used as the bob of a pendulum. The students are asked to place their bets on the water surface tipping to one side or the other of the sphere or staying normal to the supporting thread. It is unusual not to find a range of opinions. Once the experiment is done and the final possibility is found to be the true state of affairs (see the figure below), the students appreciate better that the fluid is in freefall along its trajectory and there can be no pressure gradient in this direction. After exploring the case of a free-falling lift, we can ask what difference is caused by the minute variation in the acceleration due to gravity from the top to the bottom of the lift. Now the students are ready to return to the spacecraft and work out these tidal accelerations there – the force field that will determine where the dust will settle.

One of the nice benefits of these ‘kitchen sink’ experiments is that the students tend to look on them as open fresh territory. We suggest a contrast with a traditional physics experiment that has attached to it a very concrete outcome. Students are honed in to those observables that lead them to the answer. They are accordingly less likely to observe the general nature of the phenomenon in hand. A nice example to illustrate this uses the acrylic sphere again. Partially filled with water, the sphere is suspended from a wound rubber band and released. The rise of the fluid surface up the sphere is impressive, and students can watch to see how the fluid surface changes shape and note the propagation of small surface waves as the spin speed and direction change during the oscillation. So we find that investigating the effects of changing rotation, and the unusual shape of the vessel, can give renewed life to the classical problem of a cylinder of fluid in uniform rotation.

Figure 1: The water level in an oscillating pendulum

Figure 2 (below): The wax candle mould (separated into two hemispheres to show the small drainage hole)