Demystifying the Equations of Sedimentary Geology

Larry Lemke (Wayne State University) ldlemke@wayne.edu

Instructor's Notes

There are pros and cons to having your students take independent notes (distilling or copying what you write on the board or overhead projector along with what you say), versus providing them with hard or electronic copies of your notes and presentations. In general, I like to let my students take their own notes as I deliver chalkboard lectures peppered with questions aimed at the students to help them anticipate where the lecture is going and to keep them alert. For lectures with more than one or two equations, however, I often provide students with a note-taking template consisting of my lecture notes with key parts removed. This helps them to stay focused on the discussion about what the equations mean and how they're applied (rather than worrying about copying the equations into their notes without error). Several examples of such abridged course notes are provided in the *supplemental materials* for this exercise.

A few tips for successful application of the Demystification Techniques are also given here:

1. Surgical Strikes

- Use these at the beginning of class, when students are fresh.
- Explain to the students what you're doing and *why* you're doing it – "We're going to review these mathematical concepts now so that when we apply them to sedimentology later in the lecture you can concentrate on how they are used without getting lost in the details of the math."
- Stay focused – only target what you'll actually use in the day's lecture.
- Try to keep it brief – 5 to 10 minutes tops!
- Don't be afraid to quickly review a surgical strike topic at the beginning of a subsequent lecture – review and reinforcement can work wonders for many students.

2. Unit Analysis

- Use this technique routinely after presenting or deriving a new equation.
- Use common units to move toward generic (Mass, Length, Time) units:

$$Stress = \frac{Force}{Area} = \frac{N}{Area} = \frac{kg \cdot m/s^2}{m^2} = \frac{kg}{m \cdot s^2} = \frac{M}{LT^2}$$

- Unit analysis can also be applied to derived quantities or units. Consider, for example, the centipoises unit for dynamic viscosity, μ:

$$\mu = \frac{shear\_stress}{velocity\_gradient} = \frac{\tau}{\frac{dv}{dy}} = \frac{\frac{M}{LT^2}}{\frac{1}{T}} = \frac{kg \cdot m/s^2}{m^2} = \frac{kg}{m \cdot s^2} = \frac{M}{LT}$$

$$centipoise = cp = \frac{g}{m \cdot s} = \frac{M}{LT}$$ √ makes sense as a unit for dynamic viscosity

3. Perturbation Interrogation

- Use *Perturbation Interrogation* in combination with *Unit Analysis*.
- This technique is particularly effective for quantities that can be expressed as ratios:

Example $Froude\_Number = F_r = \frac{U}{\sqrt{gL}}$

Will the Froude number increase or decrease as the mean flow velocity, U, increases?
Will the Froude number increase or decrease if the water depth, L, decreases?

- It also works quite well for equations of chemical reactions and chemical equilibria:

Example $H_2O + CO_{2(g)} + CaCO_{3(s)} \Leftrightarrow Ca^{2+}_{(aq)} + 2HCO^{-}_{3(aq)}$

What happens if we add more CO_2 to the atmosphere?
The reaction is driven to the ____ (right/left) and more $CaCO_3$ is ____ (dissolved/precipitated).
What happens if CO_2 gas escapes from the water?
The reaction is driven to the ____ (right/left) and more $CaCO_3$ is ____ (dissolved/precipitated).

- The approach can then be extended to tap into students intuition about the chemical response to physical changes in the system:

Example $H_2O + CO_{2(g)} + CaCO_{3(s)} \Leftrightarrow Ca^{2+}_{(aq)} + 2HCO^{-}_{3(aq)}$

What will happen if:
A. The water temperature increases? (winter turns to summer)
B. The atmospheric pressure decreases? (a hurricane comes by)
C. The water is agitated? (breaking waves over a shoal)
D. The water pressure is decreased? (upwelling)

Final note: Equations do not always come easily to me. To truly understand them, I really have to think about them. For me, this sometimes means deriving them from first principles if I can, but often it means tearing them apart and analyzing them with unit analysis and perturbation. In this way, I develop my intuition for the relationship that the equation is meant to express and for how that relationship can be expected to change in response to changing system conditions.

Many of my students are encouraged to learn that their instructor has to work hard to grasp the meaning of the equations we utilize in class. Therefore, I make a point of letting them know that understanding equations is hard work, but it is not impossible with the right attitude and techniques. By demonstrating the use of several of my favorite techniques (unit analysis and perturbation) in class, I model the reasoning processes that I use to dig into equations and hope that my students will adopt similar habits.