Scientists as Writers: Commonalities and Distinctions of Writing across Different Disciplines

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Elements of science writing common with other disciplines

- A research paper, lab report, or proposal needs a clear thesis statement
- Has clearly constructed arguments
- Cites prior work
- Discusses the context and connection to the existing body of research
- Distinguishes facts & observables from interpretation & speculation
- It is an iterative process that involves reinterpreting the work in the eyes of the intended audience

Elements of writing that are unique to the natural sciences

- Use of passive voice is acceptable
- Writing in the first person is common
- Sentence construction often uses short, declarative statements
- Mostly avoids using parallelism and analogy in favor of concrete details
- There is a general appreciation for a simple construction style
  - This is done to free cognitive capacity for processing of complex mathematical or analytical statements.
- Strong emphasis on graphs and mathematical expressions
  - Equations should be considered as part of the text, where “=“ is considered a verb
- Elegance is evaluated in terms of efficiency and precision

Reynolds number scaling of the influence of boundary layers on the global behavior of laboratory quasi-Keplerian flows

by E. M. Edlund and H. Ji, *PRE* **92**, 043005 (2015).

Abstract:

We present fluid velocity measurements in a modified Taylor-Couette device operated in the quasi-Keplerian regime, where it is observed that nearly ideal flows exhibit self-similarity under scaling of the Reynolds number. In contrast, nonideal flows show progressive departure from ideal Couette as the Reynolds number is increased. We present a model that describes the observed departures from ideal Couette rotation as a function of the fluxes of angular momentum across the boundaries, capturing the dependence on Reynolds number and boundary conditions.

Extracts from the introduction

1. Establish context
2. Identify open question(s)
3. Describe new contributions

That the global properties of an extended system may be mapped to the boundaries is an idea that has found success in holographic theories of general relativistic systems [1 ,2] and in magnetically confined plasmas [3 ,4]. **We report on a similar behavior** observed in incompressible hydrodynamic flows in a Taylor-Couette (TC) apparatus where it is observed that certain characteristics of the global flow are largely dictated by the boundaries.

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While there is some disagreement between studies as to whether hydrodynamic turbulence can be induced in QK flows, the balance seems to lean toward the negative, at least insofar as incompressible turbulence is considered, and points to the important role of magnetohydrodynamic effects in astrophysical systems. **However, while it is known that QK flows are linearly stable it remains unknown whether** there exists a nonlinear transition to turbulence, even for incompressible hydrodynamic systems.

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Such trends are revealing of whether these systems are dominated by boundary interactions or internal dynamics, a distinction with important consequences for the applicability of such experiments to interpretation of astrophysical systems, especially at large Reynolds numbers. First, through the experiments reported here **we identify two necessary criteria** that define constraints on the boundary configurations that allow near-ideal flows to develop. We then discuss the competing roles of radial (Stewartson) boundary layers and axial (Ekman) boundary layers, from which **we develop a model** that describes the quantitative departure of the rotation profiles from ideal Couette flow as a function of the angular momentum fluxes through the boundaries.

Extracts from the body

1. Clearly labeled graphics
2. Captions explain the graphics
3. Equations are part of a sentence

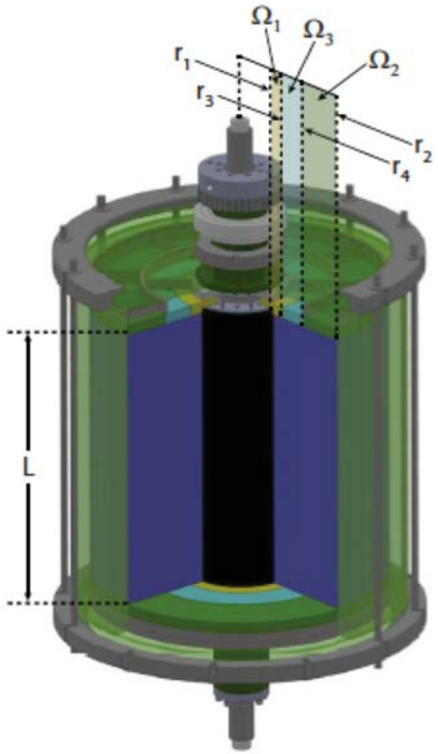

FIG. 1. (Color online) Illustration of the HTX device at PPPL showing the inner cylinder in black, the out cylinder in green, and the working fluid in dark blue. The segmented axial boundaries show the inner cylinder extensions in yellow, the independent rings in light blue, and the outer cylinder extensions in green.

ratio of $\Gamma = L/(r_2 - r_1) = 2.97$ (see Fig. 1). Corresponding components on the top and bottom are driven by the same

the boundary pressure. Following the intuition motivated by these simulations, we define a function Δp that characterizes the average pressure difference between ideal Couette rotation and boundary rotation,

$$\Delta p = \frac{\rho r_g^3 \Delta\Omega^2}{\Delta r} \int_{s_1}^{s_2} \int_{s_1}^{s} \left(\omega_C^2 - \omega_b^2\right) s'\, ds'\, ds. \qquad (3)$$

For the wide-ring configuration the zeros of Δp and Φ_z are widely separated, meaning that no circumstance exists

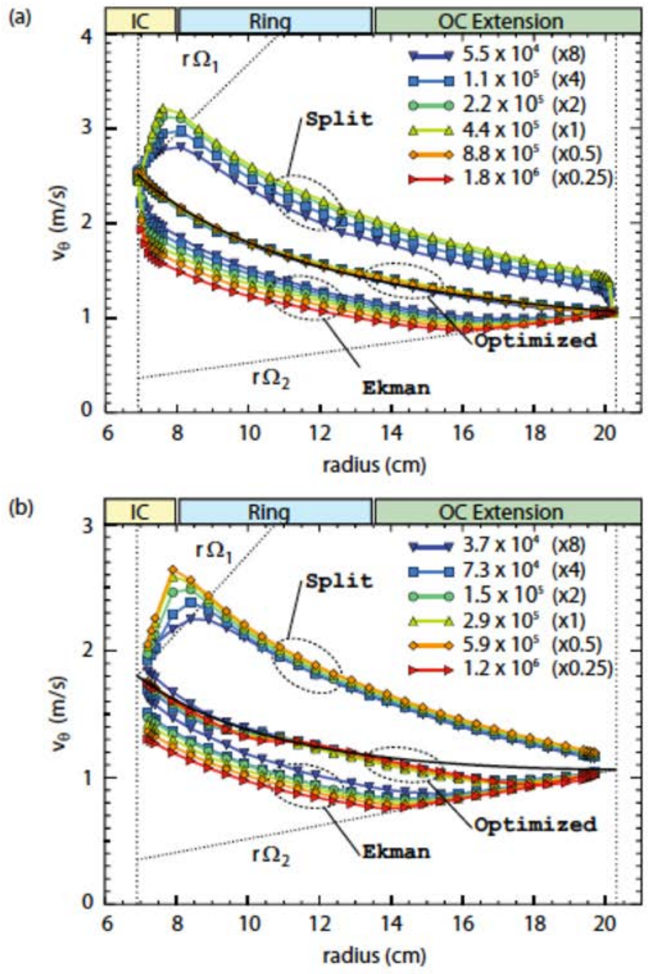

FIG. 2. (Color online) Scaled measurements of v_θ at various Re_s for (a) $q = 1.8$ and (b) $q = 1.5$.

$r_g^2(\Omega_1 - \Omega_2)/(r_2^2 - r_1^2)$. As a function of azimuthal velocity the Couette solution is $v_C(r) = r\Omega_C$. It is interesting that while the Ekman and Split configurations exhibit progressive departure from ideal Couette as the Reynolds number is increased, the shape of the Optimized cases is nearly invariant with respect to scaling of the Reynolds number.

Extracts from the conclusion

1. Restate what has been proved
2. Connection back to larger field
3. Path for future work

We have shown that nearly ideal flows exhibit profile shape invariance under scaling of the Reynolds number, an effect we interpret through the dual conditions of vanishing axial angular momentum flux and vanishing pressure differential that are nearly simultaneously satisfied, offering predictive capability for selecting optimized boundary conditions and in experimental design. **The strongest piece of evidence in support of this model is** the prediction of self-similarity of the profiles with respect to scaling of the Reynolds number only for cases in which the axial flux of angular momentum and the pressure differential vanish nearly coincidentally, a prediction in excellent agreement with the observations presented in Fig. 2.

…

Recalling that multiple experiments [7 ,19 ,20] and simulations [25 ,27] have observed a nearly uniform axial structure through the bulk of the fluid volume, the existence of large axial fluxes **naturally raises the following question:** What allows the bulk flows to depart from the solid-body rotation forced by the boundaries? Intuition based on the Taylor-Proudman theorem for Rayleigh-stable flows, that is $dv_\theta/dz \approx 0$, would suggest that the bulk should tend to follow the boundary.

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Another problem for future experiments, both physical and numerical, will be to explore in greater detail how the very large, local fluxes of angular momentum are redistributed near the axial boundaries with only minor effect on the bulk flow in the Optimized configurations. Nonoptimized boundaries, like the Split and Ekman configurations, show progressive departure from the ideal Couette flow as the Reynolds number is increased, in agreement with the expectations of a dominant axial flux of angular momentum.

The importance of graphics in science writing as an efficient vehicle of information

- Graphical abstract
  - Ideally, a single image that tells the story of your article.
  - Ask someone who hasn't read the manuscript if they understand what the paper is about based on the graphic. Is critical content missing? Can extraneous material be removed?
  - Print out the graphic. Is the text readable? Do the graphics and lines look crisp and easy to see?
  - See handout

- What makes a good graph?
  - Axes, units, titles, appropriate use of space, visually clear and unambiguous
  - See handout

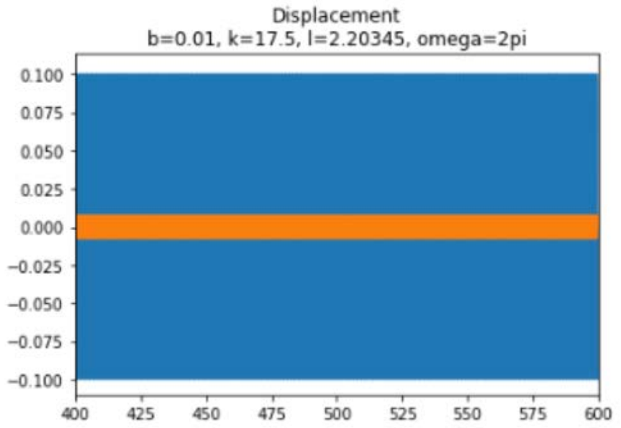
Examples of typical assignments

- Lab reports
  - Regular format (standards should be provided by the lab instructor)
  - Will likely include graphs or graphical presentation of some kind
- Scientific manuscripts
  - Formats can vary substantially based on journal
  - Must include an abstract
  - Usually will contain multiple figures
- Grant/project proposals
  - Must have a clearly defined statement of research intent or a hypothesis
  - Must define the scope of the work and required resources
  - The goal should be to convince the reviewer of the capability of the researcher

Examples of iterated student work

First draft:

simulation of what will be happening to the pendula over time. I was also able to write and read our data to a file to make it easier to run many simulations without confusion. We can find maximum amplitude at specific frequencies and plot the simulations at these frequencies. We are also able to keep track of the energy of the system and see how it changes over time with another plotting function. The plot showing the relationship between amplitude and time is shown below.



One future research opportunity revolves around further program development that can plot wavelength versus time. Given the fact that we can plot position over time and developed a

Second draft:

V. Results

The main purpose of running the simulation was to acquire a graph that compares the amplitude of the masses versus the frequency of oscillation. However, this section also serves to provide a graph of displacement as well as velocity versus time of a mass(5^{th}). The plot for displacement versus time of the fifth mass at a frequency of 1 Hz is provided below in figure 2.

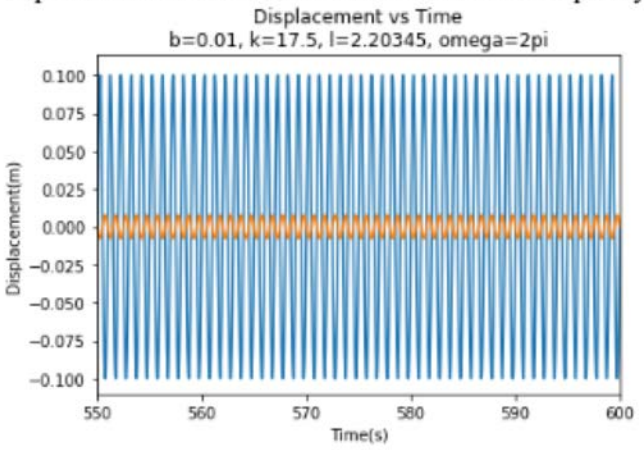


Figure 2: Plot of Amplitude vs Time of the 5^{th} mass

Figure 2 provides a graph of driven amplitude versus time(blue) as well as mass amplitude versus time(orange) of the 5^{th} mass from 550 to 600 seconds. As evidenced by the figure, the driver amplitude was set at 0.1 meters and the amplitude of oscillation of the mass is shown to be approximately 0.01 meters. A time varying damping parameter, a spring constant k_{sp}, and effective pendulum length L were included in the calculation and are provided at the top of the graph. Figure 3 displays a graph of velocity versus time of the same mass at the same driving frequency.

Questions to ask of students that relate to the general content of a paper or proposal:

1. What is the main research question?
2. What is the connection of this work to the larger field?
3. Specifically, how does this work relate to prior work in the field?
   - May not apply for lab reports.
4. What is the hypothesis of the present work? Or, if there is no explicit hypothesis, how does this work address an outstanding question in the field?
   - Is this the strongest hypothesis possible?
5. Does the abstract convey the essential information that a reader should know to determine whether this paper is worth their time?

Note: these questions are fairly generic and could be applied to almost any discipline.

Questions to ask of students that relate to the general content of a paper or proposal:

6. What is the general outline of the experimental or theoretical process that is needed to establish the main point?
7. Does the paper reflect the logical flow as defined in answer to the previous question?
   - A correct answer here is likely not a chronological presentation of the research.
   - Rarely does research proceed in a linear-in-time process, so a chronological discussion of the research should be a big red flag.
8. Do the graphics tell the story to the paper as if they read like a Cliff’s Notes guide to the study?

Note: these questions are more specific to scientific studies.

Questions to ask of students that are specific to each figure in the document:

1. Why is this figure significant?
2. What does this figure explain?
3. Does the caption provide sufficient explanation to allow for interpretation of the figure without getting lost in details?
4. Do the scales in the figure accurately convey the significance, or perhaps lack thereof, of the measurement or the result?
5. How does the figure represent the larger discussion in the text?
6. Where is the figure explicitly referenced in the text, and is this done so in a meaningful way?
7. Does the figure efficiently use the space given to it?

Discussion

- Evaluation of scientific writing:
  - We generally operate with a “sparse” aesthetic
    - Less is more
    - Short, declarative sentences
    - Precision of meaning is a virtue that is respected
    - A picture is worth a thousand words
  - The document should be both textually and graphically complete
    - The paper is often built around the graphics that sell the work
    - Some research philosophies begin by outlining the paper that is desired and the figures that would accompany it
  - The document should have a logical flow of ideas, often proceeding as follows:
    - Background & problem statement or hypothesis (somewhat field-specific how this is done)
    - Discussion of methods and/or experimental apparatus
    - Presentation of data & analysis
    - Conclusions, often including an outlook to future studies
- Is there something that we can provide to help aid your conversations with students about science writing?