Note 1: Notations below that appear as, e.g., "[1], Sec. 2.3," refer to Section 2.3 in Reference [1], listed at the end of this document. All of the References are available at the front desk of the UVM Library as materials for math 4990 on reserve.

Note 2: Topic selection is on the first-come-first-served basis: That is, the person who first asks me to assign a given Topic to them will be the *only* one presenting this Topic.

Note 3: To repeat from (and, perhaps, add to) the document "Guidelines for your midterm and final presentations," posted on the course website:

- Allow yourself sufficient time (a.k.a. start early) for selecting a Topic. This will likely require your browsing through several Topics, which will/should require a few hours and likely even a few days.
- The presenter of a Topic, and *not the instructor*, is responsible for working through and understanding all the derivations. You are welcome and encouraged to contact the instructor if you have a question, but this will only be effective if you do so well in advance of your *rehearsal*. Remember that lack of planning by you will not constitute an emergency for me.
  You *are* allowed to use *any* resources, including AI, to help you understand any details of your project. However, keep in mind that *it is solely you*, and not your resources, who *are responsible for your explaining every detail of your project*.
- You must spend a sufficient amount of time presenting details of your setup. In most Topics, this will require you to use pictures or diagrams. You must also select what details of your Topic's derivation you need to present to make your presentation logical (all other derivations must still be in a report that you will submit to me).

Note 4: The only acceptable Resources for topic selection other than those listed in the References are the American Journal of Physics and the European Journal of Physics, both of which you can access online as long as you are on UVM's network. An example from the latter journal is a paper by V. Ivchenko, "Beyond Stevin's law: the Janssen effect," Eur. J. Phys., vol. 44, 025006 (2023). If you decide to use either of these Resources instead of the pre-approved Topics listed below, you must obtain my permission in writing to present a paper that you have selected. Remember that: (i) This must be done at least 10 days before the *first scheduled rehearsal* (which may not necessarily be yours); and (ii) I will critically review your proposed papers and will reject them if I find them inadequate as a topic for a final presentation (please note the vagueness and hence the broadness of this formulation).

Approved Topics for Final Presentations

1. [1], Secs. 6.5 & 6.6: Stability of a reaction in a chemical tank.
2. [1], Sec. 7.3: Flow of fluids through porous media.
3. [1], Sec. 7.4: Closure of a cavity in a salt dome.

4. [1], Sec. 7.5: Filtration of smoke in a cigarette.

5. [1], Secs. 8.1–8.3: Mechanism of overthrust faulting in geology.[1]

6. [1], Sec. 9.3: Thermal explosion and self-ignition.

7. [1], Secs. 9.4 (Boundary-layer heat transfer problems) and either Sec. 9.5 (film condensation and film boiling) or Sec. 9.6 (natural convection and film melting).

8. [1], Secs. 14.1–14.3: Probabilistic model of a conveyor.

9. [1], Secs. 15.1[2]–15.3: Independent events leading to the Poisson distribution.

10. [1], Secs. 15.4–15.6: Waiting line problem in a factory.

11. [1], Secs. 16.1–16.3: Random networks in a plane.

12. [1], Secs. 16.4 & 16.5: Surface films made of needle-shaped crystals.

13. [2]: Derivation and generalizations of the principle behind the Euler–Lagrange equations.

    - Secs. 1.4.2, 1.4.3 (ignore unfamiliar names such as "co/contravariant"), Definition (1.82), and Secs. 1.4.5, 1.4.10 (spherical coordinates only).
    - The Hamiltonian Principle: Secs. 3.4.1–3.4.5. *Briefly* present Example 3.8 as a setup, *focusing* on writing the kinetic energy in generalized coordinates from the start (Eq. (3.127)), as opposed to using its Cartesian form as in Lecture 7.

      Present Eqs. (3.128) without derivation and state (also without derivation) that they amount to Eq. (3.129). Briefly show, as in Example 3.9, that when conditions (3.130) hold, Eqs. (3.128) reduce to (3.133).
    - Present Sec. 3.4.6. Work out every detail in Example 3.10 (of course, including all equations in (3.143)).

14. Based on [3], Chap. 16; see also link to YouTube videos below: The concept of Independent Component Analysis (ICA).

    - Read Secs. 1 (skipping Sec. 1.1) and 2. Some of the details of the derivations, e.g., an explanation of why Var(θ) needs to be extremized, is not made clear in [3]. Therefore, you may supplement the reading by watching [4] and [5]. In the latter video, an explanation of the extremizing Var(θ) is found around minute 9.

      Present the motivation/setup and the outline of the SVD-based approach. Note that:
      (i) The rotation–scaling–rotation picture at the end of Sec. 1 was explained in Topic 5 of the Midterm project (see Resource "My handwritten notes on SVD" posted there).
      (ii) Note that the averaging mentioned briefly at the beginning of Sec. 1.2 and better explained in the videos is accomplished in Sec. 2 by summation over data points $j = 1, \cdots, N$.
      (iii) You must present essential details of the derivation up to the computation of kurtosis

[1] At the end of Sec. 8.3 the authors report a discrepancy with experimental evidence. You can mention this, but should not follow up, as a resolution of that discrepancy is dealt with in Secs. 8.4 and 8.5.

[2] The material presented from this section must be restricted to what pertains to Secs. 15.2 and 15.3.

in Sec. 2.3. For the kurtosis part, you should present only the reason as to why it is computed but skip the derivation.

- Present your own experiment similar to that in Sec. 3 (see also [6]). That is, you may use any two images of your choosing;[3] as a simple example, you may split the image posted for the Midterm project and split it into two parts (say, left and right).
  Note that:
  (i) The first step of processing the images is to make them have a zero mean value.
  (ii) The virtual copy of the book posted on the course webpage uses Python, whereas the video [6] and the physical copy of the book uses Matlab. You may use either, but you are fully responsible for understanding the commands you use.
  Make sure to present a conclusion whether the ICA has worked well or not; if it did not work well, make a hypothesis as to why this could be the case.

15. [7], Secs. 5.1–5.3 up to Eq. (5.12):[4] Column buckling problem.

16. [7], Secs. 6.1–6.3 & 6.5: Car following problem.

17. [7], Secs. 8.1 & 8.2 up to Eq. (8.8):[5] Shallow water wave equations.

18. [7], Secs. 12.1–12.3: Analysis of residential areas in a city.

19. [7], Secs. 15.1–15.3: Economically sensible forest harvesting.

References

[1] "Applications of undergraduate mathematics in engineering," B. Noble, Ed., Mathematical Association of America, 1967.

[2] J.N. Reddy and M.L. Rasmussen, "Advanced Engineering Analysis," Wiley, 1982.

[3] J.N. Kutz, "Data-driven modeling & Scientific computation," Oxford University Press, 2013.[6]

[4] `https://www.youtube.com/watch?v=LscooUyktz4` (Independent Component Analysis (ICA) Using Singular Value Decomposition).

[5] `https://www.youtube.com/watch?v=olKgmOuAvrc` (Independent Component Analysis 2).

[6] `https://www.youtube.com/watch?v=Ad6kMhJbqoY` (Independent Component Analysis 3).

[7] F.Y.M. Wan, "Mathematical Models and Their Analysis," Harper & Row, Pubs., 1989.

[3] which, of course, you must make to be equal size when converted to a matrix
[4] You must related Eq. (5.9) and the inline equation just before (5.12) to Lecture 4.
[5] In particular, Eq. (8.7) must be confirmed.
[6] A link to its pdf is posted on the course website, and a physical copy of the book is placed on reserve in the Library.