

**Course Syllabus – Fall 2026**  
**CLIM 412/GEOL 412 & CLIM 512**  
**Physical Oceanography**

**MW 10:30-11:45 pm, East Hall 134**

Instructor: Barry A. Klinger  
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**Office Hours:**  
Tue 1-3 (office & Zoom)  
and by appointment.

**Catalog Description**

Course describes the global patterns of temperature, salinity, currents and waves in the world's oceans, and how these patterns influence marine biota, climate, and human activity. Course introduces key concepts which explain physical features of the ocean ranging from microscopic turbulence to global circulation. **3 credits**

**Prerequisites:** MATH 113 or MATH 115, and PHYS 160 or PHYS 243, or permission of instructor.

**Student Evaluation**

**Homework:** 8-12 problem sets. See **Homework Guide** on p 4.

**Project:** Term paper on physical oceanography subject. See separate guide to project.

**Exams:** Midterm and final with mixture of mathematical problems and short essay questions.

**Different Levels:** Graduate version of class has additional questions on problem sets and exams and higher expectations for term paper.

**Grades:** Homework 25%, Term Paper 25%, Midterm 20%, Final Exam 30%

**Mathematical Level of Course**

Physical oceanography at a professional level makes wide use of vector calculus (such as MATH 213 or MATH 215). Just as calculus concerns how a quantity varies in one dimension, vector calculus concerns multiple dimensions because ocean quantities depend on the three dimensions of latitude, longitude, and depth. This course is taught on the assumption that students are not familiar with vector calculus. However, some of the readings use the notation of vector calculus. In many cases, deep knowledge of advanced math is not necessary to understand the conclusions, and the course will teach students enough notation to follow text which uses it.

Graduate students familiar with vector calculus should consider taking CLIM 712 rather than this course.

## Recommended Reading

Different students may find different reading options most useful, so the class has a recommended reading list rather than required reading.

| Required Textbook                                                                                                     |                                                                                                                                        |
|-----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Knauss, J. A., and N. Garfield, 2016: <i>Introduction to Physical Oceanography</i> , Waveland.                        | <i>Comprehensive and well-organized, some advanced math but most sections understandable to less mathematically advanced students.</i> |
| Optional Recommended Textbook                                                                                         |                                                                                                                                        |
| Afanasyev, Y. D., 2016: <i>Physical Oceanography: A Short Course for Beginners</i> , CreateSpace Independent Platform | <i>Very concise, hits major points, moderate amount of math.</i>                                                                       |

## Background Reading

Students may find these textbooks useful for additional information related to the course.

| Textbooks and Notes – Background Reading                                                                                                                                                                                                       |                                                                                                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Klinger, B. A., and T. W.N. Haine, 2019: <i>Ocean Circulation in Three Dimensions</i> , Cambridge University Press                                                                                                                             | <i>Observational, conceptual, and theoretical look at large-scale ocean circulation.</i>                                                    |
| Marshall, J., and R. A. Plumb, 2007: <i>Atmosphere, Ocean and Climate Dynamics: An Introductory Text</i> , 344 pp., Academic Press.                                                                                                            | <i>Conceptual and mathematical basis of ocean and atmosphere fluid dynamics for undergraduates and graduate students.</i>                   |
| Talley, L. D., G. L. Pickard, W. J. Emery, and J. H. Swift, 2011: <i>Descriptive Physical Oceanography, An Introduction (6<sup>th</sup> Edition)</i> , 555 pp, Elsevier.                                                                       | <i>Comprehensive observational textbook.</i>                                                                                                |
| Colling, A. (ed.), 2001, <i>Ocean Circulation</i> , 2 <sup>nd</sup> edition, Butterworth-Heinemann<br><br>Open University Course Team, 2000, <i>Waves, Tides, and Shallow-Water Processes</i> , 2 <sup>nd</sup> edition, Butterworth-Heinemann | <i>Very understandable and no advanced math, but need 2 books to cover course and organization of 1<sup>st</sup> book is not very good.</i> |

## Learning Goals

Graduates of the class should understand

- basic techniques of physical oceanography
- distributions of salinity, temperature, velocity, and other variables in the ocean
- key elements of theories of ocean waves and circulation
  - fundamental laws, including effects of rotation, pressure, friction
  - roles of different forces in driving ocean behavior
  - role of ocean in climate, biological productivity
- Process of analyzing and solving simple problems in physical oceanography

## Lecture Outline (see course outline for detailed schedule and readings)

1. Introduction: purpose and methods of course, observation methods
2. Distribution of Properties: math review, seawater, surface maps
3. Equations of Motion: heat and water exchange, forces
4. Earth's Rotation: Coriolis force, geostrophy
5. Wind-Driven Flow: Ekman transport, upwelling
6. Wind-Driven Gyres: major gyres, western boundary currents
7. Deep Meridional Overturning
8. Gravity Waves and Mixing
9. Waves in a Rotating Fluid; Eddies
10. Tides: forcing and ocean response
11. Coasts: estuaries, river outflow plumes, fronts
12. Oceans & Climate: global warming, El Nino, and climate variability

*Lecture outline is subject to change.*

## Homework Guide

- A. **Submission.** Homework is typically due about a week after being assigned. Since instructor reviews solutions in class the day it is due, **homework must be turned in by class time to get credit.** Unless students are told otherwise, homework is due as hardcopy handed in to class; if student is absent but has completed homework, they can email electronic version.
- B. **Format.** Some homework questions have a qualitative answer (student gives conceptual answer in words), but many questions are mathematical problems. Some problems involve simply figuring out the right formula to apply; for others, students will have to make an effort to figure out how to apply the right formula. All homework should be answerable based on lecture notes, sources mentioned in problem, and (occasionally) general geographic or physical knowledge which can be looked up on the internet.

- C. **Purpose.** Homework is probably the **most important part of the class**. It is impossible to do well on the exams if student has not mastered the homework first. The purpose of the homework is to train students how to use physical principles to deduce answers to questions physical oceanographers might ask themselves about the ocean. People learn better by doing and thinking about a subject, and the questions force you to think. *Solving quantitative questions is evidence that a student really understands a principle and can apply it when needed.*
- D. **Collaboration.** Students are **encouraged to discuss homework & help each other** overcome roadblocks. This is a good way to learn the material. Students may not merely copy the homework from each other or from someone else.
- E. **Support.** Students should **start homework as soon as they can**. Please contact the instructor with any questions about the homework. Best to email questions; sometimes an email response is enough, other times student can make an appointment to discuss on Zoom or in person. There are no bad questions! Instructor would rather answer 10 questions in a day from a student than have the student spend 5 hours being stuck on a problem.
- F. **Workload.** Most individual problems sets should take most students 3-6 hours to fully complete. If a student is taking 9 hours or more a week, that is a definite sign that student should get more help from the instructor. But if a student is having trouble answering after 10 minutes spent on a problem, maybe just more time is required.
- G. **Completeness.** Be sure to [concisely] show your work so instructor can see chain of reasoning leading to answer. Students get more credit for a wrong final answer with mostly correct reasoning than a correct final answer with no indication of where it came from. Here are some useful steps for solving math/physics problems.
1. What variable am I looking for?
  2. What information about known variables is given by the problem?
  3. What principles may be relevant for this problem? Check your notes.
  4. Find an equation or equations that have both the known and unknown variables.
  5. Using variable names ( $v, T, L$  etc.) rather than numbers, manipulate the equation to form an equation that gives *unknown variable = formula with known variables*
  6. If a number is asked for, stick in numbers to get numerical answer.
  7. Does the answer make sense? If you find speed = 3 million meters/sec, maybe you made a mistake somewhere!
- H. **Format.** Hand-written homework is fine. If you want to create homework online, note that Microsoft Office has an equation editor which you get in and out of with [Alt] =, and which allows you to type things like " $\beta^2 + \{1/2\}x_n$ " which will appear as  $\beta^2 + \left(\frac{1}{2}\right)x_n$ . More info at <https://support.microsoft.com/en-us/office/write-an-equation-or-formula-4f799df7-4ca4-4670-afd3-6135768b01d0>

## Artificial Intelligence (AI) Policy

**Homework:** Do not use AI (example: chatgpt) to do homework. I do not believe you will learn the material well if the AI does it for you. Also, chatgpt and other chatbots have an annoying tendency to give you an answer whether they found the correct one or not.

As mentioned in **Homework Guide**, please talk to fellow students and/or contact the instructor with any questions about the homework or for hints when you are stuck.

**Term Project:** Do not use AI (such as chatgpt) to write, outline, or otherwise create your report or your presentation. You may use AI to help you do your literature search for the project. It is sometimes hard to draw a distinction between researching and writing, but the example below should give you the spirit of the difference.

Suppose you are writing a paper on “Variations in the Strength of El Nino”.

You can ask: “Find papers about variations in the strength of El Nino in the peer-reviewed scientific literature.”

You should not ask: “How does the strength of El Nino vary from year to year?”

## George Mason University Policies

Please read the GMU guidelines at <https://stearnscenter.gmu.edu/home/gmu-common-course-policies/> for information about

- Academic Standards
- Accommodations for Students with Disabilities
- FERPA and Use of GMU Emails
- Title IX Resources and Required Reporting,