



Planning for Autonomous Robots (ENPM661) Sections 0101, 0201, 0301 and RO01

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Credits: 03

Term: Spring 2024

Course Dates: January 24th – May 9th

Course Times:

0101: Tuesdays 7:00 pm - 9:40 pm

0201: Tuesdays 4:00 pm - 6:40 pm

0301: Tuesdays 1:00 pm - 3:40 pm

RO01: Online

Classrooms:

0101: TBD and Online

0201: JMP 3201

0301: TBD

Canvas/ELMS: <https://umd.instructure.com/courses/1360031>

Course Description

Today, we are witnessing a growing interest in the Internet of Things and an accelerating momentum in the development of new smart technologies that are changing people's daily lives. Robots have become indispensable elements of this universal system. This technological advancement enables people to integrate automation into their personal lives, assisting them with routine tasks and providing the freedom to focus on their favorite daily activities and professions. These mobile devices must be able to perceive, plan, act, and interact with the environment.

A notable example of such technology is the self-driving car, which undoubtedly will revolutionize people's lives. The substantial investments made by large enterprises in the development of smart cars have created enormous career opportunities for robotic engineers. This course aims to provide essential knowledge for developing and implementing path planning algorithms to enable navigation and manipulation of robotic systems, allowing them to perform a vast variety of autonomous tasks. Ultimately, this could significantly enhance the quality of life for people.

Prerequisites

There are no official prerequisites for this course, but students should have intermediate programming skills (Python) and basic algebra knowledge for this course.

Learning Outcomes

After successfully completing this course you will be able to:

- Analyze different problem-specific uncertainties and choose the best path-planning method for each planning problem
- Define the time-complexity of different path-planning algorithms
- Apply different planning methods to find a feasible/optimal path
- Implement different path-planning algorithms in a real robot



- Create the map for an unknown environment using SLAM techniques

Required Materials

Reading

LaValle, Steven M. Planning Algorithms. Cambridge University Press, 2006. Available for free online: <http://planning.cs.uiuc.edu/>.

Software

Pycharm; Python

Hardware/Software

Linux – Ubuntu 20

→ ROS2 Galactic

- Packages: Gazebo ; Rviz
- Libraries: OMPL, Hector slam

Supplemental Resources

Readings

1. Kelly, Alonzo. Mobile Robotics: Mathematics, Models, and Methods, Cambridge University of Press, 2013.
2. Thrun, Sebastian, et al. Probabilistic Robotics. Vol. 1. Cambridge, MIT press, 2005.
3. Choset, Howie, et al. Principles of Robot Motion: Theory, Algorithms, and Implementations, MIT press, 2005.
4. Siegwart, Roland, et al. Introduction to Autonomous Mobile Robots, MIT press, 2004.

Course Structure

This course includes both on-campus and online sections. To attend synchronously online, log into ELMS-Canvas at the time of the Section 0101 class (Tuesdays 7:00 pm - 9:40 pm) and select “Video Conference” from the left side menu. This will open a Zoom link to the live classroom.

For asynchronous online students, all lectures will be recorded and made available on ELMS-Canvas under “Panopto Recordings/Video Lectures” within 24 hours of the class time. Be sure to review the recorded lecture in a timely manner.

On-campus students come to class prepared to engage with the lecture and materials. Online students, be sure to log into Canvas regularly and participate in discussions and activities. Regardless of the section you are enrolled in, participation is expected.

Please note that F1 students enrolled in the on-campus section are required to attend in person. If you have a conflict on a particular day, please reach out to me in advance to discuss.

Communication Guidelines

Communicating with the Instructor

My goal is to be readily available to you throughout the semester. I can be reached by email at rmonfare@umd.edu. Please DO NOT email me with questions that are easily found in the syllabus or on ELMS-Canvas (e.g., When is this assignment due? How much is it worth? etc.), but please DO reach out about personal, academic, and intellectual concerns/questions.

While I will do my best to respond to emails within 24 hours, you will more likely receive email responses from me on Mondays, Wednesdays, and Fridays from 6 pm to 7 pm EST.

When constructing an email to me please put “ENPM 661 (Section): Your Topic” in the subject line. This will draw my attention to your email and enable me to respond to you more quickly. Additionally, please review [this link](#). By following these guidelines, you will be ensured to receive a timely and courteous response. Finally, if you



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need to discuss issues not appropriate for the classroom and/or an email, we can arrange to talk by phone, over Zoom, or in person. Send me an email asking for a meeting and we can set something up.

Announcements

I will send IMPORTANT messages, announcements, and updates through ELMS-Canvas. To ensure you receive this information in a timely fashion, make sure your email and announcement notifications (including changes in assignments and/or due dates) are enabled in ELMS-Canvas ([How to change notification settings in CANVAS](#)).

Log into our ELMS-Canvas course site at least once every 24-hour period to check your inbox and the Announcements page.

Names/Pronouns and Self-Identifications

The University of Maryland recognizes the importance of a diverse student body, and we are committed to fostering inclusive and equitable classroom environments. I invite you, if you wish, to tell us how you want to be referred to in this class, both in terms of your name and your pronouns (he/him, she/her, they/them, etc.). Keep in mind that the pronouns someone uses are not necessarily indicative of their gender identity. Visit trans.umd.edu to learn more.

Additionally, it is your choice whether to disclose how you identify in terms of your gender, race, class, sexuality, religion, and dis/ability, among all aspects of your identity (e.g., should it come up in classroom conversation about our experiences and perspectives) and should be self-identified, not presumed or imposed. I will do my best to address and refer to all students accordingly, and I ask you to do the same for all of your fellow Terps.

Communicating with your Peers

With a diversity of perspectives and experiences, we may find ourselves in disagreement and/or debate with one another. As such, it is important that we agree to conduct ourselves in a professional manner and that we work together to foster and preserve a virtual classroom environment in which we can respectfully discuss and deliberate controversial questions. I encourage you to confidently exercise your right to free speech—bearing in mind, of course, that you will be expected to craft and defend arguments that support your position. Keep in mind that free speech has its limit and this course is NOT the space for hate speech, harassment, and derogatory language. I will make every reasonable attempt to create an atmosphere in which each student feels comfortable voicing their argument without fear of being personally attacked, mocked, demeaned, or devalued.

Any behavior (including harassment, sexual harassment, and racially and/or culturally derogatory language) that threatens this atmosphere will not be tolerated. Please alert me immediately if you feel threatened, dismissed, or silenced at any point during our semester together and/or if your engagement in discussion has been in some way hindered by the learning environment.

Netiquette Policy

Netiquette is the social code of online classes. Students share a responsibility for the course’s learning environment. Creating a cohesive online learning community requires learners to support and assist each other. To craft an open and interactive online learning environment, communication has to be conducted in a professional and courteous manner at all times, guided by common sense, collegiality and basic rules of etiquette.

Grading

Grade Breakdown

Assignment	Percentage %
Class Activities	3%
2 Quizzes	10%



Five Projects plus project zero (see below)	57%
Take Home Final Exam	30%
Total	100%

Course Assignments

Students from diverse backgrounds enroll in this course every year, designed to be instructive for all and cover a broad spectrum of skills. Some may initially find the course pace slow, especially at the beginning. To accommodate this, the final project is defined early in the semester, allowing these students to focus on it after completing their bi-weekly projects.

On the other hand, some students might perceive the course workload as significantly higher compared to typical courses. Notably, this course stands out as one of the few providing hands-on training and real-world implementation of knowledge in robotics. Consequently, the instructor encourages students to view it not merely as a standard course but as a unique opportunity to develop skills essential for their future careers. The instructor is committed to supporting students in reaching this goal to the best of their abilities.

Evaluation of student performance will be based on the following criteria:

Class Activities (3 % of the overall grade)

The instructor will seek for in-session feedback from students by asking them to answer certain questions in written format. The answers will not be graded but will be used to learn about student thought processes and the improvement of students' knowledge towards the goal of the course. The evaluation will be based on how much effort each student put into learning of the fundamentals of the course. Only three absences is allowed for this course. Teamwork and academic honesty also will be considered for this evaluation.

Two Quizzes (10% of the overall grade).

- o There will be two quizzes before and after Spring break
- Quiz 1 will cover Dijkstra and A* variants and Quiz 2 will cover sampling-based algorithms.

Five Projects plus project 0 (57% of the overall grade)

Project 0: Python programming exercise (2 %)

P1: Generating nodes for 8-puzzle problem (5 % of the overall grade)

P2: Point robot planning using Dijkstra algorithm (10 % of the overall grade)

P3: Path planning for Turtlebot using A* (15% of the overall grade)

Phase 0: ROS/GAZEBO or V-REP installation

Phase 1: TBD

Phase 2: TBD

P4: Path planning for robot manipulators using OMPL (5 % of the overall grade)

Final competition: (Extra 3% to 10%) (Optional)

P5: Final Project (20 % of the overall grade)

P5-1: Research Topic Proposal and Literature Search Bibliography

P5-2: Paper Final Version; Software package; Presentation

Note: There are three options for the Final project (summarized below). Students are encouraged to choose option 1 or 2. Students who choose either option 1 or 2 are encouraged---but not required---to work in groups of 2. In contrast, students who choose option 3 must work independently. (some conditions apply for choosing option 3).

Option 1: Practical Implementation



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- o Implement a cutting-edge technique from the literature in simulation or on a real robot using sampling-based path planning method. We have turtle bots available! They use ROS in C++/Python. We also have Baxter robot.
- o Write a 6-8 page technical report in LaTeX two column IEEE conference format describing introduction/motivation, a brief background and related work, methodology including high-level pseudo code and system details, tests/demos/experiments that were run, discussion, conclusions, and bibliography.
- o In-class presentation with 10-12 slides.

Option 2: Original Research

- o Note: this option is geared more toward students who already have some knowledge of planning, or that have a specific and well-defined idea. That said, I am happy to provide ideas to students who would like to pursue this option but need help finding an original research topic to focus on.
- o The format is the same as option 1 (implement in simulation or on a real robot, IEEE 6-8 page paper and
- o 10-12 slide in-class presentation), but instead of implementing a technique from the literature the student will implement their own original ideas, ideally comparing them to at least one existing technique from the literature.

Option 3: Topic Survey Paper (Topics are limited)

- o Read 20-25 papers in the academic literature on a focused topic within the scope of planning for autonomous robots, and is expected to provide a contribution to understanding by:
 - Comparing two or more different types of approaches, each with its own body of literature.
 - Providing a new taxonomy of problems and concepts in the area.
 - Note: please read at least one published survey paper to get an idea of the structure of a survey paper.
- o Write the 10-15 page survey paper in two-column IEEE conference format.
- o In-class presentation with 10-12 slides.

Take Home Final Exam

The final exam will be 72 hours take-home exam.

Grading of Assignments

All assignments will be graded according to a predetermined set of criteria (i.e., rubric) which will be communicated to students before the assignment is submitted. To progress satisfactorily in this class, students need to receive timely feedback. To that end, it is my intention to grade all assignments within 10 days of their due date. If an assignment is taking longer than expected to grade, students will be informed of when they can expect to see their grade.

Grade Computation

All assessment scores will be posted on ELMS/Canvas page. If you would like to review any of your grades (including the exams), or have questions about how something was scored, please email me to schedule a time for us to meet and discuss.

It is expected that you will submit work by the deadline listed in the syllabus and/or on ELMS-Canvas. Late work will be penalized according to the late work policy described in the **Course Policies and Procedures** section below.



Grade Disputes: I am happy to discuss any of your grades with you, and if I have made a mistake, I will immediately correct it. Any formal grade disputes must be submitted in writing and within one week of receiving the grade.

Final letter grades are assigned based on the percentage of total assessment points earned. To be fair to everyone I have to establish clear standards and apply them consistently, so please understand that being close to a cutoff is not the same as making the cut (89.99 \neq 90.00). It would be unethical to make exceptions for some and not others.

Final Grade Cutoffs							
+	97.00%	+	87.00%	+	77.00%	+	67.00%
A	94.00%	B	84.00%	C	74.00%	D	64.00%
F	<60.0%						
-	90.00%	-	80.00%	-	70.00%	-	60.00%

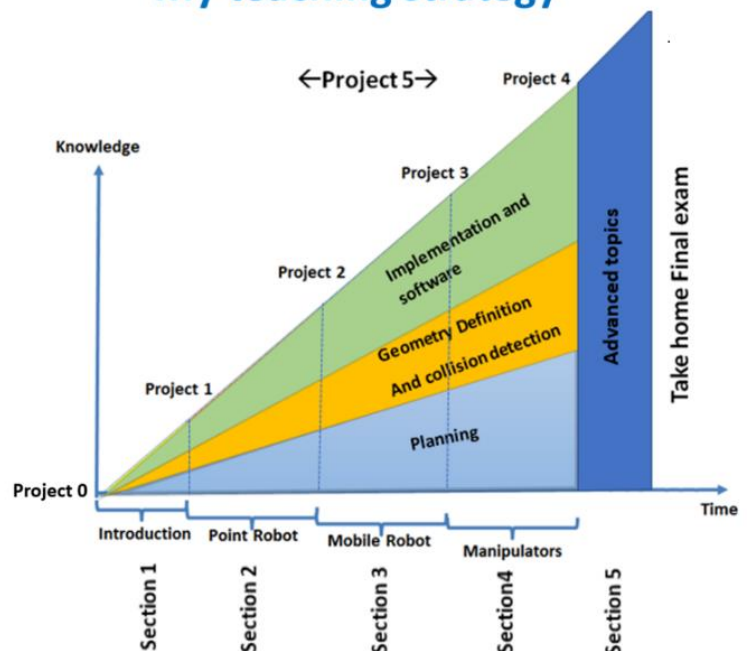
Course Outline and Schedule

Course Outline

In my experience, one of the main challenges of engineering students is to see the big picture as conventional teaching is based on introducing the topics in series not in parallel. These topics are connected concepts such as in chains with connected loops. I have observed that this process is facilitated when students are exposed to different scenarios ranging from simple to complex in which they can see a practical use of new and basic concepts before jumping into more sophisticated concepts. In my classes, I usually teach abstract concepts together with practical examples, and I try to mix theoretical training with project-based learning. The course usually starts with an introduction and basic material and the rest of the course is organized based on a series of real-world projects. For each project, I go through different chapters of the course and pick the material required to implement that project. After doing Project 1 students usually see the big picture of the course and the A to Z concepts that they will learn throughout the entire semester.

They can build on what they implemented in earlier projects to complete the new projects which are released later during the semester. This approach emphasizes the integration and interconnection of projects throughout the course, enabling students to build upon their knowledge and skills as they progress. By linking projects together, students can see the cumulative impact of their work and develop a deeper understanding of the subject matter. The figure below shows the structure of the course. The following diagram illustrates the course structure.

My teaching strategy





Course Schedule

Week #	Section # ; Dates	Topic	Deliverable
Week 1 01/29-02/04	Section 1: Introduction 01/30	1.1. Terminology 1.2. Applications	
Week 2 02/05-02/11	Section 2: Point robot 02/06 02/13	2.1. Planning (Greedy algorithm, and exhaustive algorithm) 2.2. Geometry definition and collision detection 2.3. Implementation and software	Project 0 02/11
Week 3 02/12-02/18			
Week 4 02/19-02/25	Section 3: Mobile robot 02/20 02/27 03/05 03/12	3.1. Planning (Dijkstra algorithm, A* algorithm, and weighted A*) 3.2. Geometry definition and collision detection 3.3. Implementation and software	Project 1 02/25
Week 5 02/26-03/03			
Week 6 03/04-03/10			Project 2 03/10
Week 7 03/11-03/17			Quiz 1 03/12
Week 8 03/18-03/24	Spring Break		
Week 9 03/25-03/31	Section 4: Robot Manipulators 03/26 04/02 04/09	4.1. Planning (sample-based planning) 4.2. Geometry definition and collision detection 4.3. Implementation and software	Project 3-phase 1 03/24
Week 10 04/01-04/07			Project 3-phase 2 04/07
Week 11 04/08-04/14			Project 4 04/14 Project 5 - phase 1 04/14
Week 12 04/15-04/21	Section 5: Selected topics 04/16 04/23 04/30	5.1. Planning under state transition uncertainty 5.2. Re-planning in dynamically changing environments 5.3. Planning in unknown environments	
Week 13 04/22-04/28			Competition (optional) 04/27
Week 14 04/29-05/05			Quiz 2 04/30
Week 15 05/06-05/12	05/07	Presentations	Project 5 - phase 2 05/07



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Note: This is a tentative schedule, and subject to change as necessary – monitor ELMS-Canvas for current deadlines. In the unlikely event of a prolonged university closing, or an extended absence from the university, adjustments to the course schedule, deadlines, and assignments will be made based on the duration of the closing and the specific dates missed.

Note: It is expected that students will devote about 6 to 8 hours to this course each week. Every effort has been made to evenly distribute the course requirements, and to support your understanding of the course material. However, it is likely that some weeks will require more effort on your part, and some material will require additional help beyond what is immediately available. Please reach out to me or your appropriate TA for these course-related questions, and please be prepared to put in the additional effort.

Course Policies and Procedures

The University of Maryland's conduct policy indicates that course syllabi should refer to a webpage of course-related policies and procedures. For a complete list of graduate course related policies, visit the [Graduate School website](#). Below are course-specific policies and procedures which explain how these Graduate School policies will be implemented in this class.

Satisfactory Performance

The Graduate School expects students to take full responsibility for their academic work and academic progress. The student, to progress satisfactorily, must meet all the academic requirements of this course. Additionally, each student is expected to complete all readings and any preparatory work before each class session, come to class prepared to make substantive contributions to the learning experience, and to proactively communicate with the instructor when challenges or issues arise.

Questions about Assignments

Please ask all questions you may have about an assignment by 10:00 PM the day before the assignment is due. Any questions asked after that time may not be answered in time for you to make changes to your work.

Late Work Policy

Assignments should be completed by the due date and time listed with the assignment, on the syllabus, and/or in the course calendar. If you are unable to complete an assignment by the stated due date, it is your responsibility to contact your instructor to discuss an extension, at least 24 hours BEFORE the assignment is due. Extensions are not guaranteed, but may be granted at the instructor's discretion.

Assignments submitted late will receive a 10% deduction in total grade per each calendar day late up to a maximum of three days late (i.e., there is a maximum of a 30% grade reduction for assignments submitted late). Work submitted more than three days late will not receive feedback and will automatically earn a grade of zero.

Religious Observance

It is the student's responsibility to inform the instructor of any intended absences for religious observances in advance. Notice should be provided as soon as possible but no later than the end of the schedule adjustment period.

Academic Integrity

For this course, some of your assignments will be collected via Turnitin on ELMS/Canvas. I have chosen to use this tool because it can help you improve your scholarly writing and help me verify the integrity of student



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work. For information about Turnitin, how it works, and the feedback reports you may have access to, visit [Turnitin Originality Checker for Students](#)

The University's Code of Academic Integrity is designed to ensure that the principles of academic honesty and integrity are upheld. In accordance with this code, the University of Maryland does not tolerate academic dishonesty. Please ensure that you fully understand this code and its implications because all acts of academic dishonesty will be dealt with in accordance with the provisions of this code. All students are expected to adhere to this Code. It is your responsibility to read it and know what it says, so you can start your professional life on the right path. **As future professionals, your commitment to high ethical standards and honesty begins with your time at the University of Maryland.**







It is important to note that course assistance websites, such as CourseHero, or AI generated content are not permitted sources, unless the instructor explicitly gives permission. Material taken or copied from these sites can be deemed unauthorized material and a violation of academic integrity. These sites offer information that might be inaccurate or biased and most importantly, relying on restricted sources will hamper your learning process, particularly the critical thinking steps necessary for college-level assignments.

Additionally, students may naturally choose to use online forums for course-wide discussions (e.g., Group lists or chats) to discuss concepts in the course. However, **collaboration on graded assignments is strictly prohibited unless otherwise stated.** Examples of prohibited collaboration include: asking classmates for answers on quizzes or exams, asking for access codes to clicker polls, etc. Please visit the [Office of Graduate Studies' full list of campus-wide policies](#) and reach out if you have questions.

Finally, on each exam or assignment you must write out and sign the following pledge: **"I pledge on my honor that I have not given or received any unauthorized assistance on this exam/assignment."**

If you ever feel pressured to comply with someone else's academic integrity violation, please reach out to me straight away. Also, **if you are ever unclear** about acceptable levels of collaboration, **please ask!**

To help you avoid unintentional violations, **the following table** lists levels of collaboration that are acceptable for each graded exercise. Each assignment will contain more specific information regarding acceptable levels of collaboration.

	 OPEN NOTES	 USE BOOK	 LEARN ONLINE	 GATHER CONTENT With AI	 ASK FRIENDS	 WORK IN GROUPS
Class Activities	✓	✓	✓	✓	✓	✓
Quizzes	✓	✓	✓	---	---	---
Projects	✓	✓	✓	✓	✓	✓
Take Home Final Exam	✓	✓	✓	✓	---	---

Course Evaluation

Please submit a course evaluation through Student Feedback on Course Experiences in order to help faculty and administrators improve teaching and learning at Maryland. All information submitted to Course Experiences is confidential. Campus will notify you when Student Feedback on Course Experiences is open for you to



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complete your evaluations at the end of the semester. Please go directly to the [Student Feedback on Course Experiences](#) to complete your evaluations. By completing all of your evaluations each semester, you will have the privilege of accessing through Testudo the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.

Copyright Notice

Course materials are copyrighted and may not be reproduced for anything other than personal use without written permission.

Tips for Succeeding in this Course

1. **Participate.** I invite you to engage deeply, ask questions, and talk about the course content with your classmates. You can learn a great deal from discussing ideas and perspectives with your peers and professor. Participation can also help you articulate your thoughts and develop critical thinking skills.
2. **Manage your time.** Students are often very busy, and I understand that you have obligations outside of this class. However, students do best when they plan adequate time that is devoted to course work. Block your schedule and set aside plenty of time to complete assignments including extra time to handle any technology related problems.
3. **Login regularly.** I recommend that you log in to ELMS-Canvas several times a week to view announcements, discussion posts and replies to your posts. You may need to log in multiple times a day when group submissions are due.
4. **Do not fall behind.** This class moves at a quick pace and each week builds on the previous content. If you feel you are starting to fall behind, check in with the instructor as soon as possible so we can troubleshoot together. It will be hard to keep up with the course content if you fall behind in the pre-work or post-work.
5. **Use ELMS-Canvas notification settings.** Pro tip! Canvas ELMS-Canvas can ensure you receive timely notifications in your email or via text. Be sure to enable announcements to be sent instantly or daily.
6. **Ask for help if needed.** If you need help with ELMS-Canvas or other technology, IT Support. If you are struggling with a course concept, reach out to me and your classmates for support.

Student Resources and Services

Taking personal responsibility for your learning means acknowledging when your performance does not match your goals and doing something about it. I hope you will come talk to me so that I can help you find the right approach to success in this course, and I encourage you to visit the [Counseling Center's Academic Resources](#) to learn more about the wide range of resources available to you. Below are some additional resources and services commonly used by graduate students. For a more comprehensive list, please visit the Graduate School's [Campus Resources Page](#).

Accessibility and Disability Services

The University of Maryland is committed to creating and maintaining a welcoming and inclusive educational, working, and living environment for people of all abilities. The University of Maryland is also committed to the principle that no qualified individual with a disability shall, on the basis of disability, be excluded from participation in or be denied the benefits of the services, programs, or activities of the University, or be subjected to discrimination. The [Accessibility & Disability Service \(ADS\)](#) provides reasonable accommodations to qualified individuals to provide equal access to services, programs and activities. ADS cannot assist retroactively, so it is generally best to request accommodations several weeks before the semester begins or as soon as a



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disability becomes known. Any student who needs accommodations should contact me as soon as possible so that I have sufficient time to make arrangements.

For assistance in obtaining an accommodation, contact Accessibility and Disability Service at 301-314-7682, or email them at adsfrontdesk@umd.edu. Information about [sharing your accommodations with instructors, note taking assistance](#) and more is available from the [Counseling Center](#).

Writing Center

Everyone can use some help sharpening their communication skills (and improving their grade) by visiting [The Graduate School's Writing Center](#) and schedule an appointment with them. Additionally, international graduate students may want to take advantage of the Graduate School's free [English Editing for International Graduate Students \(EEIGS\) program](#).

Health Services

The University offers a variety of physical and mental health services to students. If you are feeling ill or need non-emergency medical attention, please visit the [University Health Center](#).

If you feel it would be helpful to have someone to talk to, visit [UMD's Counseling Center](#) or [one of the many other mental health resources on campus](#).

Notice of Mandatory Reporting

Notice of mandatory reporting of sexual assault, sexual harassment, interpersonal violence, and stalking: As a faculty member, I am designated as a "Responsible University Employee," and I must report all disclosures of sexual assault, sexual harassment, interpersonal violence, and stalking to UMD's Title IX Coordinator per University Policy on Sexual Harassment and Other Sexual Misconduct.

If you wish to speak with someone confidentially, please contact one of UMD's confidential resources, such as [CARE to Stop Violence](#) (located on the Ground Floor of the Health Center) at 301-741-3442 or the [Counseling Center](#) (located at the Shoemaker Building) at 301-314-7651.

You may also seek assistance or supportive measures from UMD's Title IX Coordinator, Angela Nastase, by calling 301-405-1142, or emailing titleIXcoordinator@umd.edu.

To view further information on the above, please visit the [Office of Civil Rights and Sexual Misconduct's](#) website at ocrsm.umd.edu.

Basic Needs Security

If you have difficulty affording groceries or accessing sufficient food to eat every day, or lack a safe and stable place to live, please visit [UMD's Division of Student Affairs website](#) for information about resources the campus offers you and let me know if I can help in any way.

Veteran Resources

UMD provides some additional supports to our student veterans. You can access those resources at the office of [Veteran Student life](#) and the [Counseling Center](#). Veterans and active duty military personnel with special circumstances (e.g., upcoming deployments, drill requirements, disabilities) are welcome and encouraged to communicate these, in advance if possible, to the instructor.