

CHE 761 Polymer Blends and Alloys

(Multiphase Polymer Systems)

Course justification

Many polymer systems of emerging commercial relevance are designed to be multifunctional, that is, they do not exhibit the properties of a single polymer. In many cases, these materials are multiphase, in which case the components segregate sufficiently in order to synergistically impart the system with the properties of each component. In this course, we shall begin with a brief review of some of the most important concepts in polymer science and use these concepts in describing equilibrium phase behavior. Methods for calculating, and measuring properties at, equilibrium will be described. Intrinsic limitations on polymer blending will lead to a discussion of methods by which such limitations can be overcome, including emulsification and reactive processing. Another means by which to produce multiphase polymeric materials is through the design of copolymers. This class of materials behaves in the same manner as surfactants, and the ordering phenomena that occur in these systems will be discussed. Thermodynamic models designed to predict the phase behavior of such materials, as well as salient experimental methods, will be described. Since a multiphase polymer system must inherently possess at least one interface separating the constituent components of the system, macromolecules at interfaces will be discussed in terms of their conformational and dynamic properties. Concepts learned from this part of the course will be extended to polymers located at impenetrable surfaces and used for adhesion or lubrication.

This graduate-level course will provide students possessing an interest in polymeric materials with the necessary background and expertise to understand and use the fundamental principles governing phase behavior and property development in multiphase polymer systems, including polymer blends and copolymers, to design material systems with designer properties. This course will complement existing polymer-related courses in the CHE, MSE, CH and TECS curricula that do not explicitly cover multiphase polymers in depth. Since most polymer systems of technological relevance (and since many polymers employed in academic and industrial research) are intrinsically multiphase, it is crucial that students interested in a career in polymer science and engineering be exposed to the material covered in this course.

Course objectives

Students will be able to:

- Predict and measure the phase behavior of multicomponent polymer systems at conditions of equilibrium.
- Identify blends of commercial importance, as well as the properties that make such blends important.
- Design modified polymer blends with specific morphologies and/or properties through the rational use of compatibilization methods.
- Measure and predict the phase behavior and properties of copolymers that self-order.
- Determine the role of polymer chains at polymer-polymer interfaces, as well as methods by which to strengthen interfaces.
- Critically examine the scientific literature and propose new research ideas.
- Use some of the theoretical concepts introduced in lecture by engaging in a computer project.

Syllabus

1. Review of fundamental principles in polymer science and thermodynamics
 - Polymer chains and entanglement
 - Conformations, mesomorphism and crystallization
 - Characteristic length and time scales
 - Chain dynamics in solutions and melts
2. Commercially important multiphase polymers and their properties
 - Engineering and high-temperature thermoplastic systems
 - Thermoset polyester systems
 - Thermoplastic elastomer systems
 - General properties and applications
 - Trade names *versus* chemical names
3. Factors governing phase equilibrium in multiphase polymer systems
 - Definition, measurement and prediction of interfacial tension
 - Review of the classical Flory-Huggins theory and its various extensions
 - Overview of emerging thermodynamic frameworks developed for multiphase polymers
 - Phase separation mechanisms and morphology/property design
 - Microphase *versus* macrophase separation
4. Measurement and estimation of the Flory-Huggins χ interaction parameter
 - Introduction and applications of light, x-ray and neutron scattering
 - Use of the random-phase approximation to extract χ
 - Calculation of χ for random copolymers and their blends
 - Estimation of χ from solubility parameters and group-contribution methods
 - Dependence of χ on composition, molecular architecture and hydrostatic pressure
5. Role of chemically specific interactions on polymer phase behavior
 - Systems exhibiting lower critical solution behavior and their properties
 - Identification of chemically specific interactions in multiphase polymers
 - Design of polymer blends that undergo exothermic mixing
 - Novel opportunities for exploiting specific interactions
6. Methods to achieve compatibilization: emulsification and reactive blending
 - Basic principles of emulsification and reactive blending
 - Requirements of macromolecular surfactants relative to interfacial strengthening
 - Kinetic- *versus* diffusion-limited reactive blending
 - Important examples of commercial systems obtained through these routes
7. Utility of block copolymers and their blends
 - Prediction and characterization of block copolymer phase behavior
 - Factors governing the morphology and property development of block copolymers
 - Response of block copolymers to homopolymer or solvent additives
 - Contemporary uses of block copolymers as templates, optical devices and membranes
 - Molecular thermodynamics of self-ordering copolymer molecules

8. Factors affecting the interface in polymer blends, alloys and copolymers
 - Classification of polymer interfaces on the basis of symmetry
 - Effects of chain ends, polydispersity and segment distribution on interfaces
 - Factors governing, and properties governed by, interfacial curvature
 - Measurements designed to elucidate the structure and properties of polymer interfaces
9. Contemporary topics in the field of multiphase polymer systems
 - Selected to introduce students to emerging technologies that employ multiphase polymers or new analytical techniques designed to facilitate the study of such materials.
10. Critical reviews of the current literature
11. Exams
 - 1 take-home midterm; 1 non-comprehensive final exam

Prerequisites:

Undergraduate courses addressing (i) phase equilibria and (ii) organic/polymer chemistry. An introductory course on polymer science would prove highly beneficial, but is not required.
Knowledge of a computer language (Fortran or C++) would be useful, but is not required.

Instruction materials:

Due to the unavailability of consolidated textbooks addressing multiphase polymers, notes will be provided for use in this course. Recommended (optional) reading:

Scaling Concepts in Polymer Physics

P.-G. de Gennes
Cornell University Press, Ithaca (1979)
ISBN 0-80141-203-X

Multicomponent Polymer Systems

I.S. Miles and S. Rostami, eds.
Longman Scientific & Technical, Harlow, U.K. (1992)
ISBN 0-58203-785-9

Physics of Polymer Surfaces and Interfaces

I.C. Sanchez, ed.
Butterworth-Heinemann, Boston (1992)
ISBN 0-75069-214-6

Polymer Blends & Alloys

M.J. Folkes and P.S. Hope, eds.
Blackie Academic, London (1993)
ISBN 0-75140-081-5

Polymer Interfaces: Structure and Strength

R.P. Wool
Hanser, Berlin (1995)
ISBN 3-44616-140-6

Thermoplastic Elastomers, 2nd ed.

G. Holden, N.R. Legge, R. Quirk and H.E. Schroeder, eds.

Hanser, Munich (1996)

ISBN 1-56990-205-4

Polymeric Compatibilizers: Uses and Benefits in Polymer Blends

S. Datta and D.J. Lohse

Hanser, Berlin (1996)

ISBN 3-44617-411-7

Physics of Glassy Polymers, 2nd ed.

R.N. Haward and R.J. Young, eds.

Chapman & Hall, London (1997)

ISBN 0-41262-460-5

Interfacial Aspects of Multicomponent Polymer Materials

D.J. Lohse, T.P. Russell and L.H. Sperling, eds.

Plenum Press, New York (1997)

ISBN 0-30645-718-0

The Physics of Block Copolymers

I.W. Hamley

Oxford University Press, New York (1998)

ISBN 0-19850-218-4

Polymer Blends

D.R. Paul and C.B. Bucknall, eds.

Wiley-Interscience, New York (2000)

ISBN 0-471-35279-9 (vol. 1), 0-471-35280-2 (vol. 2)

Block Copolymers: Synthetic Strategies, Physical Properties, and Applications

N. Hadjichristidis, S. Pispas and G.A. Floudas

Wiley-Interscience, Hoboken, NJ (2003)

ISBN 0-471-39436-X

Course information:

Instructor

Professor Richard J. Spontak

office: 919-515-4200

mobile: 919-417-3554 (texting is permissible, but identify yourself)

e-mail: spontak@ncsu.edu

Office hours

Tuesday and Thursday 4:00 – 5:00 pm ET

If you want to participate in any of my office hours, please send me an e-mail expressing your interest to meet the morning of the office hour of interest.

By appointment (contact via e-mail)

Important: To avoid having me miss your e-mail, put CHE/MSE761 in the subject line of your message.

Academic conduct:

This course adheres to all policies established by North Carolina State University with regard to the conduct of the students enrolled herein. These policies are available on the official NC State website (www.ncsu.edu) for students to read at their leisure. Students are held responsible for reading, understanding and adhering to all academic policies adopted by the University. Any questions must be brought to the instructor prior to possible infraction. The instructor draws particular attention to policies regarding plagiarism.

Grading:

Examinations

Take-home midterm examination View Lecture slides #1-#11	30%	June 21-23, 2023
Non-comprehensive take-home final examination View Lecture slides #12-#27	30%	July 28-31, 2023

Projects

Computer project	20%	June 16, 2023
Research proposal	20%	July 21, 2023

North Carolina State University

Course Policies

Policy on incomplete grades: If an extended deadline is not authorized by the instructor or department, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as an attempted course on transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student. The university policy on incomplete grades is located at <http://policies.ncsu.edu/regulation/reg-02-50-03>.

Classroom capture: Be advised that this course is being recorded for current and potential future educational purposes. By your continued participation in this recorded course, you are providing your permission to be recorded.

Supporting fellow students in distress: As members of the NC State Wolfpack community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remains a safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you. When this is the case, I would encourage you to report this behavior to the NC State Students of Concern website: <http://studentsofconcern.ncsu.edu/>. Although you can report anonymously, it is preferred that you share your contact information so they can follow-up with you personally.

ClassEval: Course and instructor evaluations: Online class evaluations will be available for students to complete during the last two weeks of class. Students will receive an email message directing them to a website where they can login using their Unity ID and complete evaluations. All evaluations are confidential; instructors will never know how any one student responded to any question, and students will never know the ratings for any particular instructors.

- Evaluation website: <https://classeval.ncsu.edu>
- Student help desk: classeval@ncsu.edu
- More information about ClassEval can be found at:
<http://www2.acs.ncsu.edu/UPA/classeval/index.htm>

Schedule: Online class evaluations will be available for students to complete during the last 2 weeks of class and become unavailable before finals begin. A reminder will be posted on the class website.

Academic integrity: Students should refer to the University policy on academic integrity found in the Code of Student Conduct (found at <http://policies.ncsu.edu/policy/pol-11-35-01>). It is the instructor's understanding and expectation that the student's signature on any test or assignment means that the student contributed to the assignment in question (if a group assignment) and that (s)he neither gave nor received unauthorized aid. Authorized aid on an individual assignment includes discussing the interpretation of the problem statement, sharing ideas or approaches for solving the problem, and explaining concepts involved in the problem. Any other aid would be unauthorized and a violation of the academic integrity policy. Unauthorized aid additionally includes accessing on-line solutions, whether they are complete or partial on-line/file copies of textbook/homework problem solutions, or paying someone to complete your homework. In addition, *any computer work submitted must be completed on your own personal computer or from your own EOS account to avoid confusion about the origin of the file, and sharing of files in any way is strictly forbidden.* All cases of academic misconduct will be submitted to the Office of Student Conduct. Students found guilty of academic misconduct will be subject to, at a minimum, a zero on the assignment in question, up to a zero for that course component (e.g., a zero for the homework portion of the final grade), or a failing grade in the course, depending on the nature of the violation. In addition, if you are found guilty of academic misconduct in the course, you will be on academic integrity probation for the remainder of your years at NCSU and may be required to report your violation on future professional school applications.

Students with disabilities: Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with the Disability Services Office at Suite 2221, Student Health Center, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation (REG02.20.01) (<http://policies.ncsu.edu/regulation/reg-02-20-01>).

Attendance regulation: <http://policies.ncsu.edu/regulation/reg-02-20-03>.

Equal opportunity: NC State University provides equality of opportunity in education and employment for all students and employees. Accordingly, NC State affirms its commitment to maintain a work environment for all

employees and an academic environment for all students that is free from all forms of discrimination. Discrimination based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation is a violation of state and federal law and/or NC State University policy and will not be tolerated. Harassment of any person (either in the form of quid pro quo or creation of a hostile environment) based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation also is a violation of state and federal law and/or NC State University policy and will not be tolerated. Retaliation against any person who complains about discrimination is also prohibited. NC State's policies and regulations covering discrimination, harassment, and retaliation may be accessed at <http://policies.ncsu.edu/policy/pol-04-25-05> or http://www.ncsu.edu/equal_op/. Any person who feels that he or she has been the subject of prohibited discrimination, harassment, or retaliation should contact the Office for Equal Opportunity (OEO) at 919-515-3148.

NC State policies, regulations, and rules (PRR): Students are responsible for reviewing the NC State University PRR's located at <http://oucc.ncsu.edu/course-rights-and-responsibilities>, which pertains to their course rights and responsibilities.

**North Carolina State University
Code of Student Conduct
www.fis.ncsu.edu/ncsulegal/41.03-codeof.htm**

ACADEMIC INTEGRITY

The free exchange of ideas depends on the participants' trust that they will be given credit for their work. Everyone in an academic community must be responsible for acknowledging, using the methods accepted by the various academic disciplines, their use of others' words and ideas. Since intellectual workers' words and ideas constitute a kind of property, plagiarism is like theft.

Furthermore, as a reader you may want to follow other writers' paths of research in order to make your own judgments about their evidence and arguments. You will depend on those writers' accuracy and honesty in reporting their sources. In turn, your readers will depend on yours.

The free exchange of ideas also depends on the participants' trust that others' work is their own and that it was done and is being reported honestly. Intellectual progress in all the disciplines demands the truthfulness of all participants.

Plagiarism and cheating are attacks on the very foundation of academic life, and cannot be tolerated within universities. Section eight (8) of the Code defines academic dishonesty and provides information on potential sanctions for violators of academic integrity.

DEFINITIONS OF ACADEMIC DISHONESTY

Academic dishonesty is the giving, taking, or presenting of information or material by a student that unethically or fraudulently aids oneself or another on any work which is to be considered in the determination of a grade or the completion of academic requirements or the enhancement of that student's record or academic career.

A student shall be guilty of a violation of academic integrity if he or she:

- represents the work of others as his or her own;
- obtains assistance in any academic work from another individual in a situation in which the student is expected to perform independently;
- gives assistance to another individual in a situation in which that individual is expected to perform independently;
- offers false data in support of laboratory or field work.

The act of submitting work for evaluation or to meet a requirement is regarded as assurance that the work is the result of the student's own thought and study, produced without assistance, and stated in that student's own words, except as quotation marks, references, or footnotes acknowledge the use of other sources.

Submission of work used previously must first be approved by the instructor.

Regulations regarding academic dishonesty are set forth in writing in order to give students general notice of prohibited conduct. They should be read broadly and are not designed to define academic dishonesty in exhaustive terms.

If a student is in doubt regarding any matter relating to the standards of academic integrity in a given course or on a given assignment, that student shall consult with the faculty member responsible for the course before presenting the work.

CHEATING

Cheating includes but is not limited to the following actions:

Copying from someone else's test or examination paper.

Possessing, buying, selling, removing, receiving, or using, at any time or in any manner not prescribed by the instructor, a copy or copies of any materials (in whole or part) intended to be used as an instrument of academic evaluation in advance of its administration.

Using materials or equipment during a test or other academic evaluation that have not been authorized by the instructor, such as crib notes, calculator, or tape recorder.

Obtaining or attempting to obtain in a fraudulent manner any material relating to a student's academic work. Such actions include theft of examination through collusion with a university employee.

Working with another or others in completing a take-home examination or assignment when the instructor has required independent and unaided action.

Attempting to influence or change an academic evaluation, grade, or record by unfair means. This would include altering academic work which has been returned to the student and which has been resubmitted without indicating that the work has been altered. This also includes changing or altering grades on grade report forms or on transcripts.

Permitting another student to substitute for one's self in an academic evaluation.

Marking or submitting an examination or evaluation material in a manner designed to deceive the grading system.

Willfully damaging the academic work or efforts of another student.

Failing to comply with a specific condition of academic integrity that has been clearly announced in a particular course.

Submitting, without prior permission of the instructor, any work by a student which has at any time been submitted in identical or similar form by that student in fulfillment of any other academic requirement at any institution.

Submitting of material in whole or part for academic evaluation that has been prepared by another individual(s) or community agency.

*****PLAGIARISM*****

Submitting written materials without proper acknowledgment of the source.

Deliberate attribution to, or citation of, a source from which the referenced material was not in fact obtained.

Submitting data that have been altered or contrived in such a way as to be deliberately misleading.

AIDING AND ABETTING OTHERS TO CHEAT OR PLAGIARIZE

Aiding and abetting others to cheat or plagiarize includes but is not limited to the following:

Giving unauthorized assistance to another or others during a test or evaluation, including allowing someone to copy from a test or examination, or arranging with others to give or receive answers via signals.

Substituting for another student in order to meet a course or graduation requirement. Permitting one's academic work to be represented as the work of another.

Providing specific information about a recently given test, examination, or assignment to a student who thereby gains an unfair advantage in an academic evaluation.

Providing aid to another person, knowing such aid is expressly prohibited by the instructor, in the research, preparation, creation, writing, performing, or publication of work to be submitted for academic evaluation.

Removing or attempting to remove, without authorization, any material relating to a class that would give another student unfair academic advantage. Unauthorized preparing for sale abstracts or transcriptions of lectures or required readings in any course. This regulation is not intended to preclude students from assisting instructors or preparing course related materials.

RESPONSIBILITY TO REPORT ACADEMIC DISHONESTY

Academic Dishonesty is a corrosive force in the academic life of a university. It jeopardizes the quality of education and depreciates the genuine achievements of others. It is, without reservation, a responsibility of all members of the campus community to actively deter it. Apathy or acquiescence in the presence of academic dishonesty is not a neutral act; histories of institutions demonstrate that such responses will reinforce, perpetuate, and enlarge the scope of such misconduct. Institutional reputations for academic dishonesty are regrettable aspects of modern education. These reputations become self-fulfilling and grow, unless vigorously challenged by students and faculty alike.

Faculty must undertake a threshold responsibility for such traditional safeguards as examination security and proctoring. All members of the University community, students, faculty and staff, share the responsibility and authority to challenge and make known to the appropriate authority acts of apparent academic dishonesty.

SANCTIONS FOR ACADEMIC DISHONESTY

The student is always placed on academic integrity probation, and given one of the following sanctions or a combination of sanctions as listed below.

The student will be placed on academic integrity probation for the remainder of the student's academic career. Note that suspension will be instituted if the academic dishonesty is committed while the student is already on academic integrity probation.

No credit on the assignment, paper, program, test or exam on which the violation occurred, or no credit for the course.

In addition to any of the other sanctions listed or in lieu of an additional semester of suspension an academic community service assignment may be given. Participation in the Academic Integrity Seminar Series.

The student will be suspended if the academic dishonesty is committed while he or she is already on academic integrity probation or when the acts committed involved advance planning, falsification of papers, forms, or documents, collaboration with others, or some actual or potential harm to other students. For example, theft of another student's returned examination will usually merit suspension, even for a first offense. In cases where the student will complete graduation requirements during the current semester, suspension is to take effect immediately. In cases where a student will complete graduation requirements in either summer session I or II, the suspension period will be applied to summer session. Suspension will be noted on the transcript. The student will be expelled if he or she is a repeat offender or in those cases where acts committed are considered to be substantial violations of academic integrity or present substantial harm to other students.

SHARING COURSE MATERIAL

The documents – both electronic and hard copies of lecture notes, lecture videos, homework assignments and solutions, exams and solutions, or handouts – made available to you for this course are intended exclusively for your personal use. You are **NOT** allowed to share any content of the class with (i) any person not signed up for the course this semester (at this or any other institution of higher learning); (ii) a personal, public or commercial website; or (iii) any other news or advertising media. Doing so will constitute a direct violation of the North Carolina State University Code of Student Conduct and will be handled accordingly.

HEALTH AND PARTICIPATION IN CLASS

Due to the Coronavirus pandemic, public health measures have been implemented across campus. Students should stay current with these practices and expectations through the [Protect the Pack](https://www.ncsu.edu/coronavirus/) website (<https://www.ncsu.edu/coronavirus/>). The sections below provide expectations and conduct related to COVID-19 issues

We are most concerned about your health and the health of your classmates and instructors/TAs.

- If you test positive for COVID-19, or are told by a healthcare provider that you are presumed positive for the virus, please work with your instructor on health accommodations and follow other university guidelines, including self-reporting: <https://healthypack.dasa.ncsu.edu/coronavirus/>. Self-reporting is not only to help provide support to you, but also to assist in contact tracing for containing the spread of the virus.
- If you feel unwell, even if you have not been knowingly exposed to COVID-19, please do not come to class.
- If you are in quarantine, have been notified that you may have been exposed to COVID-19, or have a personal or family situation related to COVID-19 that prevents you from attending this course in person (or synchronously), please connect with your instructor to discuss the situation and make alternative plans, as necessary.
- If you need to make a request for an academic consideration related to COVID-19, such as a discussion about possible options for remote learning, please talk with your instructor for the appropriate process to make a COVID-19 request.

Health and Well-Being Resources: These are difficult times, and academic and personal stress is a natural result. Everyone is encouraged to take care of themselves and their peers. If you need additional support, there are many resources on campus to help you:

- Counseling Center (<https://counseling.dasa.ncsu.edu/>)
- Health Center (<https://healthypack.dasa.ncsu.edu/>)
- If the personal behavior of a classmate concerns or worries you, either for the classmate's well-being or yours, we encourage you to report this behavior to the NC State CARES team: (<https://advising.dasa.ncsu.edu/resources-for-advisors/advisors-toolkit/cares/>)
- If you or someone you know are experiencing food, housing or financial insecurity, please see the Pack Essentials Program (<https://dasa.ncsu.edu/pack-essentials/>).

Community Standards related to COVID-19: We are all responsible for protecting ourselves and our community. Please see the community expectations and Rule 04.21.01 regarding Personal Safety Requirements Related to COVID-19 <https://policies.ncsu.edu/rule/rul-04-21-01/>

Course Expectations Related to COVID-19:

- **Personal Protective Equipment:** As a member of the NC State academic community you are required to follow all university guidelines for personal safety with face coverings, physical distancing, and sanitation. Face coverings are required in this class and in all NC State buildings. Face coverings should be worn to cover the nose and mouth and be close fitting to the face with minimal gaps on the sides. In addition, students are responsible for keeping their course/work area clean.
- **Course Attendance:** NC State attendance policies can be found at: <https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/>. Please refer to this course's attendance, absence, and deadline policies for additional details. If you are quarantined or otherwise need to miss class because you have been advised that you may have been exposed to COVID-19, you should not be penalized regarding attendance or class participation. However, you will be expected to develop a plan to keep up with your coursework during any such absences. If you become ill with COVID-19, you should follow the steps outlined in the health and participating section above. COVID 19-related absences will be considered excused; documentation need only involve communication with your instructor.
- **Course Meeting Schedule:** Your course might not have a traditional meeting schedule in Fall 2020. Be sure to pay attention to any updates to the course schedule as the information in this syllabus may have changed. Please discuss any questions you have with the instructor.

- **Classroom Seating:** To support efficient, effective contact tracing, please sit in the same seat when possible and take note of who is sitting around you; instructors may also assign seats for this purpose..
- **Technology Requirements:** This course may require particular technologies to complete coursework. Be sure to review the syllabus for these expectations, and see go.ncsu.edu/syllabus-tech-requirements to find out more about technical requirements for your course. If you need access to additional technological support, please contact the Libraries' Technology Lending Service: <https://www.lib.ncsu.edu/devices>.

Course Delivery Changes Related to COVID-19: Please be aware that the situation regarding COVID-19 is frequently changing, and the delivery mode of this course may need to change accordingly, including from in-person to online. Regardless of the delivery method, we will strive to provide a high-quality learning experience.

Grading/Scheduling Changing Options Related to COVID-19: If the delivery mode has a negative impact on your academic performance in this course, the university has provided tools to potentially reduce the impact. In some cases, another option may be to request an incomplete in the course. Before using any of these tools, **discuss the options with your instructor and your academic advisor**. Be aware that if you use the enhanced S/U, you will still need to complete the course and receive at least a C- to pass the course.

Other Important Resources

- Keep Learning: <https://dasa.ncsu.edu/students/keep-learning/>
- Protect the Pack FAQs: <https://www.ncsu.edu/coronavirus/frequently-asked-questions/>
- NC State Protect the Pack Resources for Students: <https://www.ncsu.edu/coronavirus/reactivating-campus/resources-for-students/>
- NC State Keep Learning, tips for students opting to take courses remotely: <https://dasa.ncsu.edu/students/keep-learning/>
- Introduction to Zoom for students: <https://youtu.be/5LbPzzPbYEW>
- Learning with Moodle, a student's guide to using Moodle: <https://moodle-projects.wolfware.ncsu.edu/course/view.php?id=226>