

Course Description

The theory of transformation groups mainly studies the symmetries of topological spaces (manifolds, polyhedra) as actions of subgroups of the full group of symmetries of the space with the open-compact topology. This course combines important results from the *theory of groups* with *general topology* to study invariant properties of spaces through its symmetries or via actions of groups. This course is available to any student who have the prerequisites; however, it is focused for students majoring in Mathematics.

Course Schedule and Location

The lectures will meet on Wednesdays and Fridays : 2:30 - 4:00 pm in the room MC 108.

Prerequisites

Either one of *Math 3020: Introduction to Abstract Algebra* or *Math 3120: Group Theory*, and *Math 3121: Topology*.

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

Learning Outcomes

Upon completion of this course, students will be able to:

- Characterize transformation groups on topological spaces using the main theorems from Group Theory and general Topology .
- Categorize and distinguish the fibration constructions in transformation groups: Classifying spaces, Principal and Fiber Bundles.
- Identify the Borel construction as an invariant of spaces and functions that preserve the group action.

- Apply fundamental theorems of the theory of G -space to describe invariant geometrical properties of spheres and projective spaces.
- Evaluate the rigidity of transformation groups by identifying if the action is in a topological environment or in a differential environment.

Methods of Evaluation

The following methods will be used as the assesment tools for grading this course, and their corresponding weights to compute the final grade are given in the following table.

Participation	5%
Assignments (4)	40%
Midterm Exam	25%
Final Exam	30%

- **Assignments:** There will be four worksheets (10% each) of 5-8 problems that will be addressed by applying the theories discussed in the lectures. Assignments will be assessed according to the accuracy, completeness, and thoughtfulness of your responses to the assignment questions. Each assignment must be distinctly different and is an individual student effort. It is expected that the solutions are typed in \LaTeX format. The due date of each assignment can be found in the course timetable. *No late assignments will be accepted* unless a supported absence is presented. The assignments will be uploaded in OWL in the scheduled day appearing in the course timetable.
- **Participation:** Student participation can substantially enrich the learning experience for both the students and the instructor. Discussion will be encouraged throughout the course, yet effective participation requires you to read assigned readings before coming to class. You are expected to attend all classes, and the participation grade will depend on the your attendance. Please notify me in advance if you will need to miss a class.
- **Exams:** There will be only one midterm exam which is a 1.5 hr paper based test. The scheduled time for the midterm exam can be found in the course timetable. The final exam is a 2 hr paper based test, it will be scheduled by the Registrar Office to take place during the december exam period, *Do not arrange traveling during these dates*. The final exam is cumulative and it will be based on the entire syllabus for the course. If a student misses the midterm exam, that student shall provide a documented excuse or a mark of zero will be entered for that midterm. *There will be no make-up midterms*, and the weight of the missed midterm will be transferred to the final examination. To be eligible for this arrangement, you must notify your instructor of your failure to take the test within a week of the missed midterm, and come up with a timeline acceptable to both for producing appropriate documentation for your absence. Please note that a student may NOT have 100% of their assesment based on the final examination. A

student who has not completed a substantial portion of the term work normally shall not be admitted to the final examination. Refer to the Academic Policies if the final exam is missed.

Learning Resources

Textbooks

- Bredon, Glen E. *Introduction to compact transformation groups*. Vol. 46. Academic press, 1972.

This textbook is the **main resource** which the course will follow as is a classical introduction to the theory of Transformation Groups. However, much of the independent study comes from the lecture notes, the assigned activities and material found in the following suggested literature.

- tom Dieck, Tammo. *Transformation groups*. Vol. 8. Walter de Gruyter, 2011.
- Montgomery, D., Zippin, L. *Topological transformation groups*. Courier Dover Publications, 2018
- Husain, Taqdir. *Introduction to topological groups*. Courier Dover Publications, 2018.
- Pontryagin, L.S. *Topological Groups*; Princeton University Press: Princeton, NJ, USA, 1946.

Several of these textbooks can be found at the University library (physical copies) or an e-version (PDF) can be downloaded through the library website www.lib.uwo.ca

Online Resources

- The course website can be accessed through OWL www.owl.uwo.ca. Use your UWO username and password to log in.
- All important documents (syllabus, lecture materials, assignments, exam details, announcements, etc.) will be posted on the OWL website.
- Students are responsible for checking OWL for messages and announcements on a regular basis. This is the primary method by which information will be disseminated to all students in the class.
- The Forum tool is enabled on the OWL website. Please use this forum to post and respond to questions about course content (lecture, readings, practice questions, etc). Your instructor or teaching assistant will provide signed responses. *Courtesy and respect is mandatory for all forum postings and will be monitored by the instructor.*

Course Timetable

This is a tentative schedule for the topics that will be covered in the course. Some adjustments may be made as the course progresses, depending on the rate at which individual topics are covered. There are also listed relevant dates for assignments, projects and exams. Again, these dates are tentative and changes will always be announced during class and clearly documented through the OWL site.

Week	Dates	Course Topics	Important Dates and Reminders
1	Sep 7–Sep 11	Fundamentals of Topology and Group Theory (review)	
2	Sep 14–Sep 18	General Theory of Topological groups	Sep 18: Assignment 1 posted in OWL
3	Sep 21–Sep 25	Compact and locally compact Groups	
4	Sep 28–Oct 2	Group Actions and Orbit Spaces	Oct 2: Due date to submit assignment 1. Assignment 2 posted in OWL
5	Oct 5–Oct 9	Isotropy subgroups and fixed points	
6	Oct 12–Oct 16	Introduction to homotopy theory	Oct 16: Due date to submit assignment 2.
7	Oct 19–Oct 23	G -spaces and equivariant maps	Oct 23: Midterm Exam. It will cover topics from weeks 1-5.
8	Oct 26–Oct 30	Principal bundles and classifying spaces	Oct 30: Assignment 3 posted in OWL
9	Nov 2–Nov 6		Fall Reading Week No Lectures
10	Nov 9–Nov 13	The Borel construction and introduction to equivariant theories.	Nov 13 : Due date to submit assignment 3 Assignment 4 posted in OWL.
11	Nov 16–Nov 20	Group actions on spheres and projective spaces	

12	Nov 23–Nov 27	Introduction to Differential manifolds	Nov 27: Due date to submit assignment 4.
13	Nov 30–Dec 4	Lie groups and Smooth actions	Last week of Lectures
Exam Period	Dec 7–Dec 11 Dec 14–Dec 18	December final exams period	Please do not book travel during this time

Lecture Policies

Please use the materials and resources provided on OWL and/or through class for your individual use during the course. Sharing or reproducing class materials online (for free or for profit) and/or sharing materials with individuals who are not taking the course is not acceptable without first receiving permission from the owner or creator of those resources/materials. Again, this is based on Intellectual Property rights.

Although you are welcome to use a computer/tablet during lectures and tutorials, you are expected to use the computer for scholastic purposes only, and refrain from engaging in any activities that may distract other students from learning. Please be respectful to your classmates and turn the sound off. If the professor receives complaints from other students regarding noise or other disruptive behaviour while using your electronic devices, your classroom privileges will be revoked. From time to time, the instructor may ask the class to turn off all computers, to facilitate learning or discussion of the material presented in a particular class. It is suggested to be mindful with your fellow classmates and limit the use of phones/iPods during the lectures and tutorials.

Ask your instructor and/or Teaching Assistant before you make an video/audio recording of class. This expectation provides basic respect for their privacy and personal safety, and is in keeping with Intellectual Property rights. If you would like to make video/audio recordings of our lecture sessions, please send me an email to arrange for an official permission.

Exam Policies

It is university policy that a regularly scheduled class (lecture or tutorial) takes precedence over tests and exams. Therefore, if another course schedules a test or exam that takes place during a lecture or tutorial of this class, the instructor for that course must accommodate you.

No electronic devices (calculators, laptops, tablets, phones, iPods, etc.) may be in your possession during tests and exams, even for timekeeping purposes. These devices must be left at home or with your bag/coat at the front of the room during an exam. They may not be at

your test/exam desk or in your pocket. Any student found in possession of these prohibited devices will receive a mark of zero on the test or exam.

Inclusivity Statement

It is the intent that students from all diverse backgrounds and perspectives be well-served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is the intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. Your suggestions are always encouraged and appreciated. The course is based on the premise of creating a learning environment for all students that supports a diversity of thoughts, perspectives and experiences, and honours student's identities. For example, If you have a name and/or set of pronouns that differ from those that appear in your official University records, please let me know!

Instructor Information

Name: Sergio Chaves, PhD Candidate.

Office Hours: Tuesday and Thursday from 4:00 to 5:00 pm in MC 109. Drop-in, no appointment necessary.

Email: schavesr@uwo.ca

For *Teaching Assistants* information and office hours check the OWL course site.

Email Policies

Instructors and Teaching Assistants' email should only be used for administrative purposes. In order to maximize efficiency and to allow your instructors to respond to administrative concerns as quickly as possible, emails of the following nature will not be responded to: Questions that can be answered based on the information found in this course outline. and Requests for grade increases, extra assignments, makeup labs, etc.

If you email your instructor or designated teaching assistant, you must use your Western email address. Messages from a nonWestern account may be blocked by the university's antispyam system and will be ignored.

You can expect a response to an email Message or OWL Forum posting within about 48 hours during the Monday to Friday workweek. Note that Messages or Forum questions will generally not be answered in the 24-hour period before exams; this is meant to encourage proactive studying and help-seeking behaviour. Be sure to check OWL announcements and your UWO email on a regular basis for news and updates related to the course.

Policies and Support

Academic Policies

The website for Registrarial Services is <http://www.registrar.uwo.ca>. In accordance with policy, <http://www.uwo.ca/its/identity/activatenonstudent.html>, the centrally administered e-mail account provided to students will be considered the individuals official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at his/her official university address is attended to in a timely manner.

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at this website: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf. If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or supporting documentation to the Academic Counselling Office of your home faculty as soon as possible. If you are a Science student, the Academic Counselling Office of the Faculty of Science is located in NCB 240, and can be contacted at scibmsac@uwo.ca.

For further information, please consult the universitys medical illness policy at http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf

If you miss the Final Exam, please contact your facultys Academic Counselling Office as soon as you are able to do so. They will assess your eligibility to write the Special Exam (the name given by the university to a makeup Final Exam).

You may also be eligible to write the Special Exam if you are in a Multiple Exam Situation (see http://www.registrar.uwo.ca/examinations/exam_schedule.html)

It is Faculty of Science policy that a student who chooses to write a test or exam deems themselves fit enough to do so, and the student must accept the mark obtained. Claims of medical, physical, or emotional distress after the fact will not be considered. Computer-marked, multiple-choice tests and/or exams may be subject to submission for similarity review by software that will check for unusual coincidences in answer patterns that may indicate cheating.

All required papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

This course will use **Gradescope**, an online collaborative grading and analytic platform. For information on their privacy policy, please visit their website, <https://Gradescope.com/privacy>. During tests/exams, proctors will inspect all personal belongings on your desk (and even your baseball cap if you are wearing one). If any items are discovered that are

not permitted (e.g. any electronic device or other than a non-programmable calculator, or notes) they will be confiscated and the incident will be officially reported as an academic offence. Proctors have the discretion to move students between desks during the Tests or Exam periods.

Support Services

Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 ext. 82147 for any specific question regarding accommodation. The policy on Accommodation for Students with Disabilities can be found here: www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_disabilities.pdf. The policy on Accommodation for Religious Holidays can be found here: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf.

Learning-skills counsellors at the Student Development Centre (<http://www.sdc.uwo.ca>) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling. Students who are in emotional/mental distress should refer to Mental Health at Western (<http://www.uwo.ca/uwocom/mentalhealth/>) for a complete list of options about how to obtain help. Additional student-run support services are offered by the USC, <http://westernusc.ca/services>.

Clicker Use in this Course

A clicker is a browser page or app opened on a personal WiFi device (e.g. a smartphone, tablet, or laptop). In class, instructors can ask a variety of structured questions to which you may respond by pressing the appropriate button on your device. Individual responses are collected and summarized in a graph at the front of the room. If the instructor chooses, individual responses may also be saved for future analysis.

Clicker Responsibility: The university is subscribed to and use clicker software produced by iClicker (<https://www.iclicker.com/>) because it is the company supported by Westerns technology services and is free to registered students. A student choosing to use a clicker will be responsible for (a) bringing their own device to use as a clicker, and (b) setting up their iClicker account correctly. Note that the course and instructor is not responsible (and therefore, no accommodation will be made) for WiFi failure. Clicker Academic Record. Your clicker use will be recorded in lecture and will become part of your academic record. As such, your clicker record will be afforded the same degree of security, confidentiality, and transparency that is customary for test marks, etc. Your clicker data will not be used for any non-academic or research purpose without your consent. For any research study in which you are invited to participate, you will be provided with a Letter of Information with an

opportunity to give or withhold consent. Such research will not replace the usual end of term Student Questionnaire given by the University.

Academic Integrity: Use of a clicker associated with an identity other than your own is an academic offense. Granting permission for someone else to submit answers on your behalf in your absence is an academic offence. In a test, lab, lecture, or tutorial, possession of more than one clicker device, or one associated with the identity of another student, will be interpreted as intent to commit an academic offense and will be reported as such. This means that it will be considered an academic offense to answer a clicker question using an account other than your own.

Retention of Electronic Version of Course Outlines (Syllabi)

At the same time that course outlines/syllabi are posted on the appropriate Website, each Department must forward an electronic version of items 1-5 of each course outline (syllabus) to the Office of the Dean of the Faculty or College. By the fourth week after the start of term, the Deans Office will forward all of the collected outlines to Registrarial Services, where they will be maintained in electronic form in the faculty/staff extranet for a minimum of ten years after the completion of the course. (Final retention periods and disposition will be determined by the relevant records retention and disposition schedule approved by the President's Advisory Committee on University Records and Archive).

Acknowledgment of the Science Student Donation Fund:

Mathematics undergrad courses are supported by the Science Student Donation Fund. If you are a BSc or BMSc student registered in the Faculty of Science or Schulich School of Medicine and Dentistry, you pay the Science Student Donation Fee. This fee contributes to the Science Student Donation Fund, which is administered by the Science Students' Council (SSC). One or more grants from the Fund have allowed for the purchase of equipment integral to teaching this course. You may opt out of the Fee by the end of September of each academic year by completing the online form linked from the Faculty of Science's Academic Counselling site. For further information on the process of awarding grants from the Fund or how these grants have benefitted undergraduate education in this course, consult the Chair of the Department or email the Science Students' Council at ssc@uwo.ca.