

## Math 2701 - Topology 2

### Syllabus and Topics List

**Course Overview:** This is a course in algebraic topology, a subject which has as its primary (or at least initial) goal the development of algebraic invariants to distinguish certain topological spaces up to homeomorphism or homotopy equivalence. The spaces studied in algebraic topology usually lack distinguishing features from the standpoint of point-set topology.

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**Course website:** [http://www.pitt.edu/~jdeblois/S16\\_top2.html](http://www.pitt.edu/~jdeblois/S16_top2.html)

**Office Hours:** TBD. Check the course website.

**Textbook:** *Algebraic Topology*, by Allen Hatcher. It is freely available on the internet at <https://www.math.cornell.edu/~hatcher/AT/ATpage.html>

**Prerequisites:** Basic knowledge of point-set topology and abstract algebra. Here is a list of topics from each subject with which you should be familiar:

**Point-set:** Open and closed sets, bases, product and subspace topologies, connectedness, compactness, continuous functions, the Hausdorff property.

**Algebra:** Groups, subgroups, quotient groups and homomorphisms, presentations, direct sums, direct products, and finitely generated abelian groups.

**Grades:** Your course grade will be determined as follows:

- Homework, 50%. (Assigned weekly on the course website.)
- Midterm, 25%
- Final project, 25%.

The final project will consist of either a 3-5 page paper or a talk in front of the class.

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### Topics

A brief list of the main points we covered, with additions in red & omissions struck through.

#### Basic Topology.

- Quotient spaces
- CW-complexes: **construction and recognition (Hatcher, Prop. A.2)**
- Retractions, deformation retractions, homotopy equivalence, and homeomorphism.
- The basic examples:  $\mathbb{R}^n$ ,  $\Sigma_g$  ( $g \geq 1$ ),  $S^n$ ,  $\mathbb{R}P^n$ ,  $\mathbb{C}P^n$  ( $n \leq \infty$ ). CW structures.

#### Fundamental group.

- Definition and basic properties: functoriality, **basepoint-independence**, homotopy invariance,  $\pi_1(X \times Y) \cong \pi_1(X) \times \pi_1(Y)$ .
- Free groups, free products, and presentations (**in particular, Tietze transformations**).
- Van Kampen's theorem & applications:  $\pi_1(\text{graph})$  (**Hatcher Prop. 1A.2**),  $\pi_1(\text{CW-cx})$ .
- Fundamental groups of the basic examples.

- Classical theorems: Brouwer fixed point & Borsuk–Ulam, ~~fund. theorem of algebra.~~

### Covering spaces.

- Definition and basic properties:  $\pi_1$ -injectivity and # sheets.
- **Path lifting**, homotopy lifting, and map lifting.
- The classification of covering spaces, existence of the universal cover, **Galois correspondence**.
- Deck transformations, **normal covers**, and covering space actions.

### Higher homotopy groups.

- Definition(s) and basic properties: abelian, **action of  $\pi_1$** .
- Cellular approximation;  $\pi_k S^n$ ,  $k < n$ .
- Whitehead's theorem; ~~weak homotopy equivalence; CW approximation.~~
- Fiber bundles, **homotopy lifting**, LES of a fiber bundle.
  - Example: Hopf bundle  $S^{2n+1} \rightarrow \mathbb{C}P^n$
- **Freudenthal suspension theorem**,  $\pi_n S^n$ ,  $\pi_3 S^2$ .
- Degree of  $f: S^n \rightarrow S^n$ ; basic computations (**reflections & antipodal map**).

### Homology.

- Chain complexes and homology groups.
- CW-homology.
  - Euler characteristic  $\chi$  of a finite CW-complex, **the Euler–Poincaré formula**.
  - CW-homology of the basic examples.
- Homology with arbitrary (abelian group) coefficients.
- $\Delta$ -complexes, simplicial complexes, and simplicial homology
  - Equivalence with ~~singular~~ **cellular** homology.
  - ~~simplicial approximation; the Lefschetz fixed point theorem.~~
- Singular homology
  - Definition and basic properties: functoriality and homotopy invariance.
  - **Basic computations:**  $H_0(X)$ ,  $H_n(\{\text{pt}\})$ ,  $H_n(\bigsqcup X_\alpha) \cong \bigoplus H_n(X_\alpha)$ .
  - Basic homological algebra.
    - \* Reduced homology, relative homology.
    - \* SES of chain cxes  $\rightsquigarrow$  LES in homology (definition of  $\partial$  in particular).
    - \* The LES of  $(X, A)$  and of  $(X, A, B)$ .
    - \* ~~The five lemma.~~
  - Excision and the LES of  $X/A$ , for a good pair  $(X, A)$ .
  - Local homology, **invariance of dimension**.
  - ~~Equivalence of singular and cellular homology; homotopy classification of basic examples.~~
  - The Mayer-Vietoris sequence.
- ~~Axioms and the categorical perspective.~~
- ~~Degree via homology; its computation using local degree.~~

**Cohomology.** ~~Time permitting.~~ (It didn't.)