

MATH5665: Algebraic Topology- Course notes

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Abstract

These are the lecture notes for an Honours course in algebraic topology. They are based on standard texts, primarily Munkres's "Elements of algebraic topology" and to a lesser extent, Spanier's "Algebraic topology".

1 What's algebraic topology about?

Aim lecture: We preview this course motivating it historically.

Recall that a continuous map $f : X \rightarrow Y$ of topological spaces is a *homeomorphism* if it is bijective and f^{-1} is also continuous. In this case we say X and Y are *homeomorphic* and write $X \simeq Y$.

Major Q in topology is how to determine if two spaces X, Y are homeomorphic or not.

A depends on whether they are homeomorphic or not. If they are, one usually guesses the homeomorphism. If not, one needs to be a bit more sophisticated. One usually uses *invariants* to distinguish them. Historically, the first example is below.

Euler Characteristic

Notation 1.1 We denote the n -dim unit ball by $B^n := \{v \in \mathbb{R}^n \mid \|v\| \leq 1\}$ and the n -dim unit sphere by $S^n := \{v \in \mathbb{R}^{n+1} \mid \|v\| = 1\}$.

Consider a regular polyhedron $K \subset \mathbb{R}^3$ or more generally, any polyhedron homeomorphic to the unit sphere S^2 . Let V = no. vertices, E = no. edges and F = no. faces.

Theorem 1.2 (Euler) $V - E + F = 2$.

E.g. Check the cube, tetrahedron etc.

The quantity $e(K) := V - E + F$ is called the *Euler number* of K .

Quotient spaces

Let X = topological space and \sim be an equivalence relation on the underlying set so there is a set map $\pi : X \rightarrow X/\sim : x \mapsto [x]$ where X/\sim is the set of equivalence classes $[x]$. We put the strongest topology on X/\sim so that π is continuous, viz, $U \subset X/\sim$ is open iff $\pi^{-1}(U)$ is open. The resulting topological space is called the *quotient space*.

E.g. Let $I = [0, 1] \subset \mathbb{R}$ and $X = I \times I$. We put the weakest equivalence relation on X s.t. $(0, x) \sim (1, x), (x, 0) \sim (x, 1)$ for $x \in I$. We sometimes sum up this info in the following picture:



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Ian Pickup



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