

MATH 612 (HOMEWORK 1)

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Exercise. (Exercise 1(a)) The case of $G = \mathbb{Z}$ is discussed in Example 2.42.

$$H_k(\mathbb{RP}^n; \mathbb{Z}) = \begin{cases} \mathbb{Z} & \text{for } k = 0 \text{ and for } k = n \text{ odd} \\ \mathbb{Z}_2 & \text{for } k \text{ odd, } 0 < k < n \\ 0 & \text{otherwise.} \end{cases}$$

Suppose n is even. For any abelian group G , we obtain the cellular chain complex

$$0 \rightarrow G \xrightarrow{2} G \xrightarrow{0} \cdots \xrightarrow{2} G \xrightarrow{0} G \rightarrow 0.$$

If n is odd, we obtain

$$0 \rightarrow G \xrightarrow{0} G \xrightarrow{2} \cdots \xrightarrow{2} G \xrightarrow{0} G \rightarrow 0.$$

- Suppose k is even and $2 \leq k \leq n$. The homology at $\xrightarrow{0} G \xrightarrow{2}$ is
 - 0 if $G = \mathbb{Q}, \mathbb{Z}/p^l\mathbb{Z}$ with $p \neq 2$.
 - $\mathbb{Z}/2\mathbb{Z}$ if $G = \mathbb{Z}/2^l$.
- Suppose k is odd and $1 \leq k \leq n-1$. The homology at $\xrightarrow{2} G \xrightarrow{0}$ is
 - $G/2G \cong 0$ if $G = \mathbb{Q}, \mathbb{Z}/p^l\mathbb{Z}$ with $p \neq 2$ because multiplication by 2 is an isomorphism.
 - $\mathbb{Z}/2\mathbb{Z}$ if $G = \mathbb{Z}/2^l$.
- Suppose $k = n$ and n is odd, or $k = 0$. The homology at $\xrightarrow{0} G \xrightarrow{0}$ is G .

When $G = \mathbb{Q}$, the universal coefficient theorem gives an isomorphism $H_k(X) \otimes \mathbb{Q} \cong H_k(X; \mathbb{Q})$ since \mathbb{Q} is torsion free. $\mathbb{Z} \otimes \mathbb{Q} \cong \mathbb{Q}$ and $\mathbb{Z}/2 \otimes \mathbb{Q} = 0$ because 2 is invertible in \mathbb{Q} . This agrees with the results above.

When $G = \mathbb{Z}/2^l$, we have $0 \rightarrow H_k(X) \otimes G \rightarrow H_k(X; G) \rightarrow \text{Tor}(H_{k-1}(X), G) \rightarrow 0$. If $k = n$ and k is odd, $H_k(X) = \mathbb{Z}$, so $\mathbb{Z}/2^l \cong H_k(X; \mathbb{Z}/2^l)$. If $k-1 = n$ and $k-1$ is odd, we obtain $0 \rightarrow 0 \rightarrow H_k(X; \mathbb{Z}/2^l) \rightarrow \text{Tor}(\mathbb{Z}, \mathbb{Z}/2^l) \rightarrow 0$, so $H_k(X; \mathbb{Z}/2^l) = 0$. If k is odd and $0 < k < n$, $0 \rightarrow \mathbb{Z}/2 \otimes \mathbb{Z}/2^l \rightarrow H_k(X; \mathbb{Z}/2^l) \rightarrow \text{Tor}(H_{k-1}(X), \mathbb{Z}/2^l) \rightarrow 0$. The Tor is 0 because if $k = 0$, $H_{k-1}(X) = \mathbb{Z}$ and $H_{k-1}(X) = 0$ otherwise. Thus $H_k(X; \mathbb{Z}/2^l) = \mathbb{Z}/2 \otimes \mathbb{Z}/2^l = \mathbb{Z}/2$. In any other cases, the universal coefficient theorem gives the SES $0 \rightarrow 0 \rightarrow H_n(X; G) \rightarrow 0 \rightarrow 0$. This agrees with the results above.

Exercise. (Exercise 1(b)) As discussed in Example 2.37, $H_2(N_g; \mathbb{Z}) = 0$, $H_1(N_g; \mathbb{Z}) = \mathbb{Z}^{g-1} \oplus \mathbb{Z}_2$, and $H_0(N_g; \mathbb{Z}) = \mathbb{Z}$. For an abelian group G , the cellular chain complex is

$$0 \rightarrow G \xrightarrow{d_2} G^g \xrightarrow{d_1} G \rightarrow 0.$$

As discussed in Example 2.37, $d_2(1) = (2, 2, \dots, 2)$ and $d_1 = 0$. If $1 + 1 = 0$ in G , then $H_2(X; G) = H_0(X; G) = G$ and $H_1(X; G) = G^g$. Otherwise, then $H_2(X; G) = 0$, $H_1(X; G) = G^{g-1}$ and $H_0(X; G) = G$.

Exercise. (Exercise 1(c)) For a Z -module R , we have

$$0 \rightarrow R \xrightarrow{0} R \xrightarrow{a} R \xrightarrow{0} R \rightarrow 0.$$

When $R = \mathbb{Z}$, we obtain

$$H_k(X; \mathbb{Z}) = \begin{cases} \mathbb{Z} & \text{for } k = 0, 2n - 1 \\ \mathbb{Z}_m & \text{for } k \text{ odd, } 0 < k < 2n - 1 \\ 0 & \text{otherwise.} \end{cases}$$

When R is an abelian group such that $1 + 1 + \dots + 1 = 0$ (a times), $H_i(X; R) = R$ if $i = 0, 1, 2, 3$. Otherwise, $H_3(X; R) = H_0(X; R) = R$ and all other cohomology groups are 0.