

Problem Set 8

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November 13, 2019

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1 Problem 1

1.1 Part a

Define a map

$$\begin{aligned}\phi_{\text{ev}} : \text{hom}_{\mathbb{Z}}(\mathbb{Z}_m, A) &\rightarrow A \\ (f : \mathbb{Z}_m \rightarrow A) &\mapsto f(1)\end{aligned}$$

Then noting that ϕ_{ev} is a homomorphism, forcing $f(\bar{0}) = 0_A$ (where $\bar{0} : \mathbb{Z}_m \rightarrow A$ is the zero map), we must have

$$0 = f(0) = f(m) = mf(1),$$

we must have $mf(1) = 0$ in A . So

$$\text{im } \phi_{\text{ev}} = \{a \in A \mid ma = 0\} := A[m].$$

It is also the case that

$$\ker \phi_{\text{ev}} = \{f \in \text{hom}_{\mathbb{Z}}(\mathbb{Z}_m, A) \mid f(1) = 0\} = \{\bar{0}\},$$

which follows from the fact that $\mathbb{Z}_m = \langle 1 \bmod m \rangle$ and $A = \langle 1_A \rangle$ as \mathbb{Z} -modules, so if $f(1 \bmod m) = 0_A$ then

$$f(n \bmod m) = nf(1 \bmod m) = 0$$

and so f is necessarily the zero map. So $\ker \phi = \bar{0}$.

We can then apply the first isomorphism theorem,

$$\frac{\text{hom}_{\mathbb{Z}}(\mathbb{Z}_m, A)}{\ker \phi_{\text{ev}}} \cong \text{im } \phi_{\text{ev}} \implies \text{hom}_{\mathbb{Z}}(\mathbb{Z}_m, A) \cong A[m].$$

1.2 Part 2

The claim is that $\mathbb{Z}_n[m] \cong \mathbb{Z}_{(m,n)}$, from which the result immediately follows by part 1.

Expanding definitions, we have

$$\begin{aligned}\mathbb{Z}_n[m] &= \{x \in \mathbb{Z}_n \mid mx = 0\} \\ &= \{x \in \mathbb{Z}_n \mid o(x) \mid m \text{ and } o(x) \mid n\} \\ &= \{x \in \mathbb{Z}_n \mid o(x) \mid \gcd(m, n)\} \\ &\cong \mathbb{Z}_{\gcd(m, n)},\end{aligned}$$

where the latter identification can be made by constructing

$$\begin{aligned}\phi : \mathbb{Z} &\rightarrow \mathbb{Z}_n[m] \\ x &\mapsto x \pmod n\end{aligned}$$

Then

$$\begin{aligned}\ker \phi &= \{x \in \mathbb{Z} \mid x \equiv 0 \pmod n \text{ and } mx = 0\} \\ &= \{x \in \mathbb{Z} \mid x \equiv 0 \pmod m \text{ and } x \equiv 0 \pmod n\} \\ &= \{x \in \mathbb{Z} \mid x \equiv 0 \pmod{\gcd(m, n)}\} \\ &= \mathbb{Z}_{\gcd(m, n)}.\end{aligned}$$