

# MA 598 (Algebraic Geometry): Homework 1

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**Problem 1.1 (5-lemma)**

Given a commutative diagram with exact rows

$$\begin{array}{ccccccc}
 0 & \longrightarrow & A & \longrightarrow & B & \longrightarrow & C \longrightarrow 0 \\
 & & \downarrow f & & \downarrow g & & \downarrow h \\
 0 & \longrightarrow & A' & \longrightarrow & B' & \longrightarrow & C' \longrightarrow 0,
 \end{array}$$

suppose  $f$  and  $h$  are isomorphisms. Prove that  $g$  is an isomorphism.

**Solution.** ►

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**Problem 1.2 (Snake lemma)**

Given the diagram with exact rows

$$\begin{array}{ccccccc}
 & \text{Ker } f & \longrightarrow & \text{Ker } g & \longrightarrow & \text{Ker } h & \\
 & \downarrow & & \downarrow & & \downarrow & \\
 0 & \longrightarrow & A & \longrightarrow & B & \longrightarrow & C \longrightarrow 0 \\
 & & \downarrow & & \downarrow & & \downarrow \\
 0 & \longrightarrow & A' & \longrightarrow & B' & \longrightarrow & C' \longrightarrow 0 \\
 & & \downarrow & & \downarrow & & \downarrow \\
 & & \text{Coker } f & \longrightarrow & \text{Coker } g & \longrightarrow & \text{Coker } h,
 \end{array}$$

show that the sequence

$$0 \longrightarrow \text{Ker } f \longrightarrow \text{Ker } g \longrightarrow \text{Ker } h \longrightarrow \text{Coker } f \longrightarrow \text{Coker } g \longrightarrow \text{Coker } h \longrightarrow 0$$

is exact.

**Solution.** ►

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**Problem 1.3**

Given an exact sequence of modules

$$0 \longrightarrow A \longrightarrow B \longrightarrow C \longrightarrow 0$$

fix any  $M \in R\text{-Mod}$ .

(a) Show that

$$0 \longrightarrow \text{Hom}(M, A) \longrightarrow \text{Hom}(M, B) \longrightarrow \text{Hom}(M, C)$$

is exact.

(b) Show that

$$0 \longrightarrow \text{Hom}(C, M) \longrightarrow \text{Hom}(B, M) \longrightarrow \text{Hom}(A, M)$$

is exact.

**Solution.** ►

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**Problem 1.4**

A short exact sequence

$$0 \longrightarrow A \longrightarrow B \xrightarrow{p} 0$$

splits if there is a homomorphism  $s: C \rightarrow B$  called the *splitting* such that  $p \circ s = \text{id}_C$ . In which case, we can put

$$0 \longrightarrow \text{Hom}(C, M) \longrightarrow \text{Hom}(B, M) \longrightarrow \text{Hom}(A, M) \longrightarrow 0$$

and

$$0 \longrightarrow \text{Hom}(M, A) \longrightarrow \text{Hom}(M, B) \longrightarrow \text{Hom}(M, C) \longrightarrow 0.$$

**Solution.** ►

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**Problem 1.5**

Find an example which shows that  $\text{Hom}(-, M)$  is *not* exact.

**Solution.** ► Consider the following example: let  $A = B = M = \mathbb{Z}$  and  $C = \mathbb{Z}/2\mathbb{Z}$  then the sequence

$$0 \longrightarrow \mathbb{Z} \xrightarrow{f=2} \mathbb{Z} \longrightarrow \mathbb{Z}/2\mathbb{Z} \longrightarrow 0$$

is exact, however

