

## Foundations of Geometry Exercises

### Section 17

**Lemma 1** (Exercise 17.2). *Let  $\phi : \Pi \rightarrow \Pi$  be a map of a Hilbert plane into itself. Assume that  $\overline{AB} \simeq \overline{\phi(A)\phi(B)}$  for any two points  $A, B$ . Then  $\phi$  is a rigid motion.*

*Proof.* it is clear that, if  $A \neq B$ , then  $\phi(A) \neq \phi(B)$ , hence  $\phi$  is injective.

Let us prove that it is also surjective.

- If  $A', B' \in \text{Im}(\phi)$  then  $A'B' \in \text{Im}(\phi)$ ; in fact, a point  $C'$  in  $A'B'$  is uniquely determined by the congruence class of  $A'C'$  and  $B'C'$ ; let  $C$  be the unique point on  $AB$  such that  $\overline{AC} \simeq \overline{A'C'}$  and  $\overline{BC} \simeq \overline{B'C'}$ . Then  $\phi(C) = C'$ .
- Let  $A, B, C$  be non collinear points and let  $A', B', C'$  be their images  $D' \in \Pi$  be any point, and let  $E'$  be a point such that  $A' * E' * B'$ ; then the line  $D'E'$  meets the image of  $\phi$  in at least two points, by (B4), hence it belongs to the image.

We have now to show that  $\phi$  preserves lines, betweenness and angles.

Let  $A, B, C$  be three points on a line, and assume that  $A * B * C$ . Let  $\Gamma$  and  $\Delta$  be circles of radii  $AB$  and  $BC$  centered at  $A$  and  $C$ . Then  $\Gamma$  and  $\Delta$  are tangent, the point  $\phi(B)$  will be the unique point of intersection of  $\phi(\Gamma)$  and  $\phi(\Delta)$  (which are again circles, since  $\phi$  preserves congruence of segments). Since the two circles are tangent then  $\phi(A), \phi(B)$  and  $\phi(C)$  are on a line. Moreover, since  $\phi(A)\phi(C) \simeq \phi(A)\phi(B) + \phi(B)\phi(C)$  then  $\phi(A) * \phi(B) * \phi(C)$ .

If  $\angle ABC$  is an angle, then the triangle  $\Delta\phi(A)\phi(B)\phi(C)$  is congruent to the triangle  $\Delta ABC$  by I.8, hence  $\angle ABC \simeq \angle\phi(A)\phi(B)\phi(C)$ .  $\square$

**Exercise (17.3).** In a Hilbert plane  $\Pi$ , show:

- Any rigid motion with at least three noncollinear fixed points must be the identity.
- Any rigid motion is equal to the product of at most three reflections.

# Foundations Of Mathematics Chapter 1 Foundations Of Geometry

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