

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 ϕ is a rigid motion.*

Proof. it is clear that, if $A \neq B$, then $\phi(A) \neq \phi(B)$, hence ϕ 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 ϕ in at least two points, by (B4), hence it belongs to the image.

We have now to show that ϕ preserves lines, betweenness and angles.

Let A, B, C be three points on a line, and assume that $A * B * C$. Let Γ and Δ be circles of radii AB and BC centered at A and C . Then Γ and Δ are tangent, the point $\phi(B)$ will be the unique point of intersection of $\phi(\Gamma)$ and $\phi(\Delta)$ (which are again circles, since ϕ 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 ΔABC by I.8, hence $\angle ABC \simeq \angle\phi(A)\phi(B)\phi(C)$. \square

Exercise (17.3). In a Hilbert plane Π , 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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