

Exercise 3. (A. Hatcher, Algebraic Topology, p. 38, 7.) Define  $f : S^1 \times I \rightarrow S^1 \times I$  by  $f(\theta, s) = (\theta + 2\pi s, s)$ , so  $f$  restricts to the identity on the two boundary circles of  $S^1 \times I$ . Show that  $f$  is homotopic to the identity by a homotopy  $f_t$  that is stationary on one of the boundary circles, but not by any homotopy  $f_t$  that is stationary on both boundary circles. [Consider what  $f$  does to the path  $s \mapsto (\theta_0, s)$  for fixed  $\theta_0 \in S^1$ .]

Solution

We consider the function  $f : S^1 \times I \rightarrow S^1 \times I$  given by

$$f(z, s) = (ze^{2\pi is}, s), \forall (z, s) \in S^1 \times I.$$

Obviously, the map  $F : S^1 \times I \times I \rightarrow S^1 \times I$  given by

$$F(z, s, t) = (ze^{2\pi it}, s), \forall (z, s, t) \in S^1 \times I \times I,$$

is continuous. Moreover, we have

$$F(z, s, 0) = (z, s), F(z, s, 1) = (ze^{2\pi is}, s) = f(z, s), \forall (z, s) \in S^1 \times I$$

and

$$F(z, 0, t) = (z, 0), \forall (z, t) \in S^1 \times I.$$

Therefore,  $F$  is a homotopy from  $id_{S^1 \times I}$  to  $f$  which is stationary on the circle  $S^1 \times \{0\}$ . In a similar manner we obtain the required result for the other boundary circle.

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