Homework 6

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Exercise 2-5.9 Show that a surface of revolution can always be parametrized so that

$$E = E(v),\; F = 0,\; G = 1.$$

Proof. Suppose that the axis of the surface is the z-axis and let $c = (x, 0, z) : I \to \{y = 0, x > 0\}$ be the generating curve parametrized by arc length. The surface itself is parametrized by the map $\mathbf{x} : (0, 2\pi) \times I \to \mathbb{R}^3$ given by the formula $x(u, v) = (x(v)\cos u, x(v)\sin u, z(v))$. Now we have

$$\begin{aligned}
\mathbf{x}_u &= (-x(v)\sin u, x(v)\cos u, 0)\\
\mathbf{x}_v &= (x'(v)\cos u, x'(v)\sin u, z'(v)).
\end{aligned}$$

Thus,

$$\begin{aligned}
E &= x(v)^2 \sin^2 u + x(v)^2 \cos^2 u = x(v)^2(\sin^2 u + \cos^2 u) = x(v)^2\\
F &= -x(v)x'(v)\sin u\cos u + x(v)x'(v)\sin u\cos u + 0 \cdot z'(u) = 0\\
G &= x'(v)^2\cos^2 u + x'(v)^2\sin^2 u + z'(v)^2 = x'(v)^2(\cos^2 u + \sin^2 u) + z'(v)\\
&= x'(v)^2 + z'(v)^2 = c'(v) \cdot c'(v) = 1
\end{aligned}$$

Hence, we found one such parametrization. □

Exercise 2-6.7 Show that if a regular surface S contains an open set diffeomorphic to a Möbius strip, then S is nonorientable.

Proof. Suppose that the surface S is orientable and that it contains an open subset $V \subseteq S$ diffeomorphic to the Möbius strip. Since S is orientable, by proposition 1 there exists a differentiable field of unit normal vectors $N : S \to \mathbb{R}^3$ on S. Then, because differentiability is a local property, $N|_V : V \to \mathbb{R}^3$ is a differentiable field of unit normal vectors on V. This, again by proposition 1, implies that V is orientable, which is a contradiction because V is diffeomorphic to the nonorientable Mobius strip, so S is nonorientable. □