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On the fluid flow in the anterior chamber of a human eye with slip velocity☆

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Abstract

A simple model is presented to analyze slip-flow in the anterior chamber of a human eye. It shown that under normal condition and slip condition on the cornea, the flow, whose reduced Reynolds number is small, is viscosity dominated and is driven by buoyancy effects which are present because of the temperature difference between the front and the back of the anterior chamber.

Keywords: Slip flow; Anterior chamber, human eye; Bioheat

1. Introduction

When a Newtonian fluid flows over a porous surface, it is necessary, if the governing differential system is not to be under determinate, to specify some conditions on the tangential component of the velocity of the free fluid at the porous interface. There exists an extensive analytical literature [7]. Our objective in this study is to examine using simple standard fluid dynamical models, the principal aim of this study is to show that even relatively small temperature differences could give rise to the flows that are observed. The details of clinically observed flow in the anterior chamber is caused by heat transfer with slip flow, the one of the main sources to nutrient the cornea (permeable wall) is diffusion from aqueous in the anterior chamber [8]. Fig. 1 gives a basic idea of the geometry and structure of the eye. The eye has three chambers known as the anterior (front), the posterior (back) chamber, and the vitreous

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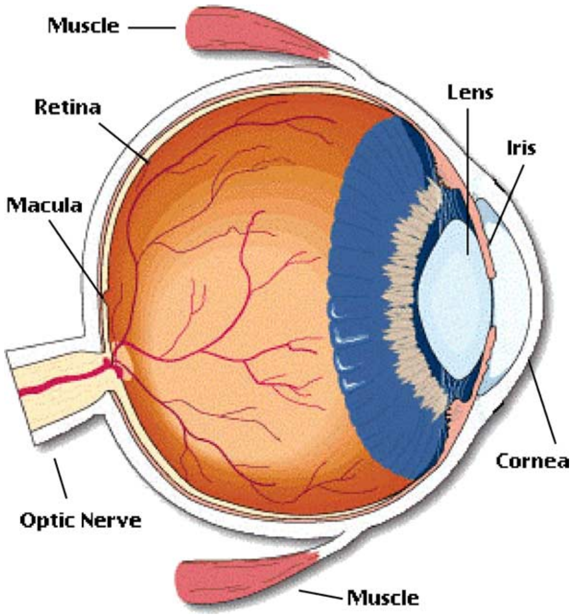

Fig. 1. The main components of a human eye.

body. The front chamber contains aqueous humor (a watery fluid). This fluid carries nutrients to different tissues in the front of the eye. The cornea is located at the front of this chamber. The cornea is the clear part of the eye. The iris is the colored part of the eye. The iris is located at the back edge of the anterior (front) chamber. The posterior (back) chamber is the smallest of the three chambers, which also contains aqueous humor (a watery fluid). The lens is located at the front of the posterior (back) chamber and is directly behind the iris. The lens is suspended by ligaments. Behind the lens is the vitreous body, which is the largest chamber of the eye. This chamber contains a thick gel-like fluid called vitreous humor. This fluid helps maintain the shape of the eye. Flow in the anterior chamber of the eye is a well-known phenomenon that has been observed; this phenomenon may result from fluid flow in the anterior chamber driven by a temperature gradient. The fluid present in this part of the eye is produced continuously by the ciliary body; it flows through the pupile aperture to the anterior chamber. The fluid may be assumed to be a linear viscous fluid with a viscosity, density and expansively identical to that of water, fluid drains from the chamber through channels in the angle between the iris and the cornea [1].

2. Motivation and modeling assumptions

We consider flow driven by thermal effects in the anterior chamber of the eye between the cornea and the pupil. Fig. 2 shows the flow that we wish to consider. We assume that the fluid is contained between $z=0$ and a solid (cornea) impermeable boundary at the cornea $z=h(x,y)$. This latter boundary is exposed to temperature t_0 and at the pupil/iris $z=0$, the temperature is T_1 which we consider to be close to body temperature and thus is in excess of T_0. The patient is assumed to be in an upright position so that gravity acts along the positive x-axis. According to classical Boussinesq model [2] for thermally-driven