INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

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Programme of Study	:	Ph.D.

Thesis Title: Pore-Scale Transport Physics: Insights into Fluid Flow and Interfacial Dynamics

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Thesis Submitted to the Academic Division	:	MECHANICAL ENGINEERING
Date of completion of Thesis Viva-Voce Exam	:	19.05.2026
Key words for description of Thesis Work	:	**Paper-based microfluidics, Capillary-driven flow, Effective viscosity, Droplet generation, Analyte trapping, Methanol detection, Non-Newtonian fluids, Phase-field modeling**

SHORT ABSTRACT

Capillary-driven flow in porous media plays a central role in numerous natural and engineered systems, from fluid transport in plant tissues to the operation of low-cost diagnostic devices. Motivated by these transport phenomena, this thesis advances the understanding of wicking dynamics, non-Newtonian biofluid behaviour, droplet generation, and colorimetric sensing within paper substrates. Through an integrated analytical–experimental–numerical framework, the work systematically examines how liquid properties, pore geometry, and fiber-scale interactions govern flow and analyte transport in paper networks. Concentration-dependent wicking in thick gel blot paper is elucidated using a modified modeling framework that accounts for saturation-based permeability, revealing distinctive front evolution patterns. Passive generation of oil droplets in paper-based pathways is demonstrated as a pump-free alternative for microscale droplet manipulation. The role of fluid rheology is further explored using NaCMC solutions and human blood, highlighting the influence of viscosity, hydrogen bonding, and cellular content on flow heterogeneity and analyte trapping relevant to lateral flow assays. Finally, a paper-based colorimetric platform is developed for rapid methanol detection in alcoholic beverages, supported by numerical estimation of a quantitative colorimetric index. Together, these studies deepen the fundamental insight into capillary-mediated transport and enable the design of robust, affordable paper-based diagnostic technologies.