Microfluidics (ME60310)/ Micro-scale Fluid Flow and Heat Transfer (ME41616), Mid-Semester Examination, February 2015, IIT Kharagpur, Full Marks = 60

All questions are compulsory

Q1.

Answer the following questions in brief:

(a) What are the ranges of typical flow rates in practical devices having micrometer length scales?
(b) Why is slip phenomenon more intuitive in gases than in liquids?
(c) What makes DNA amenable to be be manipulated by electric field?
(d) Why does ultra-violet irradiation on a TiO_2-coated substrate alter the surface wettability?
(e) Why does pinch off phenomenon occur for confined droplets in shear flow on substrates with high wettability?
(f) What is the difference between a droplet and a vesicle?
(g) What is the motivation of studying biological cells in microfluidic confinements?
(h) What are the advantages of a micro heat pipe as compared to a traditional heat pipe?
(i) What is the basic principle of physics that can be exploited in synthetic leaves for power generation?
(j) What is the working principle of a microfluidic logic gate?

[1.5×10 =15 Marks]

Q2.

(a) Using Reynolds Transport Theorem, derive a differential equation for mass conservation considering a non-deformable control volume that moves at a time dependent velocity $\vec{V}_{cv}(t)$ relative to an inertial reference frame.

(b)State the assumptions under which the following are valid (symbols have usual meaning):

(i) $0 = \frac{\partial \tau_{ij}}{\partial x_j} + b_i$

(ii) $\tau_{ij} = -p\delta_{ij} + C_{ijkl}e_{kl}$

(iii) $\rho \frac{Dh}{Dt} - \frac{DP}{Dt} = Q''' - \nabla.\vec{q}''$

(iv) $\frac{\partial}{\partial t}(\rho C_i) + \nabla \bullet (\rho \vec{V} C_i) = \nabla \bullet (\rho D \nabla C_i)$

[9+ 6 =15 Marks]

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Q3.

The cross section of a microchannel is equilateral triangle with sides of length l and a horizontal base. Flow in the channel is produced by an imposed axial pressure gradient $\frac{dP}{dz}$. Setting up a coordinate system with origin at the apex of the triangle with the y-axis bisecting the angle and positive downwards and x axis as horizontal, derive an approximate expression relating the volume flow rate through the channel as a function of the pressure gradient.

[15 Marks]

Q4.

Consider a steady plane Couette flow in which the upper plate moves parallel to itself at a speed of U_p and the lower plate is stationary. Gap between the plates is H. Water is sucked from the bottom plate at uniform speed v_s through small pores. Water is injected at the same rate through pores in the top plate. Let $\varepsilon = \frac{v_s H}{\nu}$ be small; ν being the kinematic viscosity of the fluid. Let $\overline{y} = \frac{y}{H}$. Assuming $\frac{u}{U_P} = u_0\left(\overline{y}\right) + \varepsilon u_1\left(\overline{y}\right)$, derive the expressions for $u_0\left(y\right)$ and $u_1\left(y\right)$. State any assumptions that you make.

[15 Marks]