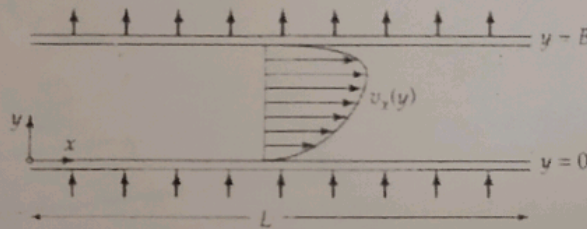




**Instructions:** Answer all questions. Closed book, closed notes examination. All symbols carry their usual meaning. Assume missing data suitably. Follow the five step problem solving methodology. Data required are included in the question paper.

1. (15 marks) A fluid flows in the positive  $x$  direction through a long flat duct of length  $L$ , width  $W$  and thickness  $B$  where  $L \gg W \gg B$ . The duct has porous walls at  $y = 0$  and  $y = B$  so that a constant cross flow can be maintained, with  $v_y = v_0$  a constant, everywhere.



- (a) List all assumptions and JUSTIFY each of them.  
(b) Choose appropriate co-ordinate system and reduce the corresponding EOM.  
(c) Show that the velocity profile for the system is given by:

$$v_x = \frac{(\mathcal{P}_0 - \mathcal{P}_L)B^2}{\mu L} \frac{1}{A} \left( \frac{y}{B} - \frac{\exp(Ay/B) - 1}{\exp(A) - 1} \right)$$

where  $A = Bv_0\rho/\mu$  and  $\mathcal{P}$  is the modified pressure.

2. (10 marks) Using summation notation prove that:

$$[\mathbf{u} \times [\mathbf{v} \times \mathbf{w}]] = \mathbf{v}(\mathbf{u} \cdot \mathbf{w}) - \mathbf{w}(\mathbf{u} \cdot \mathbf{v})$$