Unit 6 - Week 4

Course outline

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- Lecture 17 : Some exact solutions of the Navier Stokes equation
- Lecture 18 : Interfacial boundary conditions and example of thin film flows
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Assignment Solution

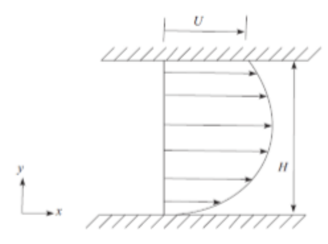
Assignment 4

The due date for submitting this assignment has passed.
As per our records you have not submitted this assignment.

Due on 2019-08-28, 23:59 IST.

1) **Common Data for Questions 1 to 6:** *1 point*

Consider steady, incompressible, fully developed flow of a constant property Newtonian fluid between two plane parallel plates located a distance H apart as shown in the figure below. The upper plate moves with a constant velocity U towards the right, whereas the lower plate is stationary. In addition to the shear, an axial pressure gradient $\frac{\partial p}{\partial x}$ also acts on the flow.



We define a non-dimensional pressure gradient as

$$P = \frac{H^2}{2\mu U}\left(-\frac{\partial p}{\partial x}\right)$$

Assertion (A): The resultant velocity profile will be a linear superposition of simple Couette flow (purely shear-driven flow) and plane Poiseuille flow (purely pressure-driven flow).

Reason (R): This superposition is possible because the non-linear convective acceleration is zero for both simple Couette flow and plane Poiseuille flow.

(A) Both A and R are true, and R is the correct explanation of A.

(B) Both A and R are true, but R is not the correct explanation of A.

(C) A is true, but R is false

(D) A is false, but R is true.

(E) Both A and R are false.

- a
- b
- c
- d
- e

No, the answer is incorrect.
Score: 0
Accepted Answers:
a

2) Which among the following statements about the resultant velocity profile is/are correct in case of favourable pressure gradients ($P > 0$)? *1 point*

(A) When $0 < P < 1$, the velocity profile exhibits a maximum somewhere below the moving plate.

(B) When $0 < P < 1$, the velocity decreases monotonically from U at the moving plate to zero at the stationary plate.

(C) When $P > 1$, the velocity profile exhibits a maximum somewhere below the moving plate.

(D) When $P > 1$, the velocity decreases monotonically from U at the moving plate to zero at the stationary plate.

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
b
c

3) Which among the following statements about the resultant velocity profile is/are correct in case of an adverse pressure gradients ($P < 0$)? *1 point*

(A) When $-1 < P < 0$, a back flow occurs near the fixed plate.

(B) When $P < -1$, the velocity decreases monotonically from U at the moving plate to zero at the stationary plate.

(C) When $-1 < P < 0$, the velocity decreases monotonically from U at the moving plate to zero at the stationary plate.

(D) When $P < -1$, a back flow occurs near the fixed plate.

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
c
d

4) The value of P for which the shear stress on the upper moving plate vanishes is *1 point*

(A) 1

(B) -1

(C) -3

(D) 0

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
a

5) The value of P for which the shear stress on the bottom stationary plate vanishes is *1 point*

(A) 1

(B) -1

(C) -2

(D) 0

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
b

6) The value of P for which there is no net flow through the channel is *1 point*

(A) 1

(B) -1

(C) -2

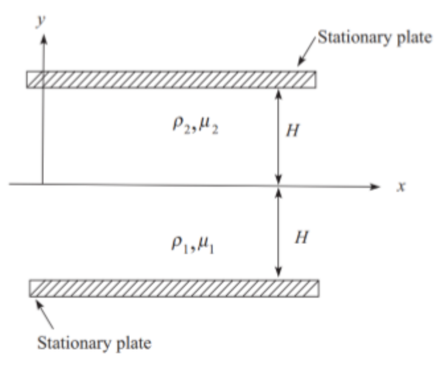
(D) -3

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
d

7) **Common Data for Questions 7 and 8:** *1 point*

Two viscous, immiscible fluids of same density ($\rho_1 = \rho_2$) but different viscosities flow in separate layers between two stationary parallel plates located at $y = \pm H$ as shown in the figure below. The two fluid layers are of equal thickness H and their interface is flat. The dynamic viscosity of the upper fluid is four times that of the lower fluid ($\mu_2 = 4\mu_1$). The flow is driven by a constant favourable pressure gradient of $\frac{\partial p}{\partial x} < 0$. Assume the flow to be steady, fully developed and the plates to be infinitely large along the z-direction.



The velocity of the lower fluid at the interface is

(A) $-\frac{1}{5\mu_1}\frac{\partial p}{\partial x}H^2$

(B) $-\frac{3}{5\mu_1}\frac{\partial p}{\partial x}H^2$

(C) $-\frac{4}{5\mu_1}\frac{\partial p}{\partial x}H^2$

(D) $-\frac{1}{2\mu_1}\frac{\partial p}{\partial x}H^2$

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
a

8) The magnitude of the shear stress acting on the lower fluid at the interface is *1 point*

(A) $-\frac{3}{5}\frac{\partial p}{\partial x}H$

(B) $-\frac{4}{5}\frac{\partial p}{\partial x}H$

(C) $-\frac{3}{10}\frac{\partial p}{\partial x}H$

(D) 0

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
c

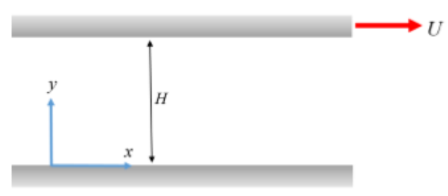
9) **Common Data for Questions 9 and 10 :** *1 point*

Under small-scale microflow conditions, the "no-slip" boundary condition at the solid surface may not be valid. One way to characterize slip in liquids is the Navier slip condition which relates the slip velocity at the solid surface to the local velocity gradient normal to the wall:

$$u_{\text{slip}} = u - u_{\text{solid}} = l_s\left(\frac{\partial u}{\partial n}\right)_{\text{wall}}$$

where l_s is called the slip length, u is the component of the fluid velocity tangential to the solid surface, u_{solid} is the tangential velocity of the solid surface and n is the direction normal to the solid surface into the fluid.

Two infinite parallel plates separated by a distance H, contain a Newtonian fluid of dynamic viscosity μ and density ρ between them. The upper plate moves with a constant velocity U towards the right and the lower plate is stationary as shown in the figure below. No axial pressure gradient acts on the flow. The Navier slip condition is valid at both the walls.



The velocity profile between the plates is given by

(A) $u = \frac{Uy}{h}, v = 0$

(B) $u = \frac{U(y + l_s)}{h}, v = 0$

(C) $u = \frac{U(y + l_s)}{h + l_s}, v = 0$

(D) $u = \frac{U(y + l_s)}{h + 2l_s}, v = 0$

(E) $u = \frac{U(y + 2l_s)}{h + 2l_s}, v = 0$

- a
- b
- c
- d
- e

No, the answer is incorrect.
Score: 0
Accepted Answers:
d

10) The magnitude of the shear stress acting on the moving plate is *1 point*

(A) $\frac{\mu U}{h}$

(B) $\frac{\mu U}{h + l_s}$

(C) $\frac{\mu U}{h + 2l_s}$

(D) 0

- a
- b
- c
- d

No, the answer is incorrect.
Score: 0
Accepted Answers:
c