学院 UC联合　专业、班 ME01　年级 18　学号 20186103　姓名 [illegible]　考试教室 A8302

公平竞争、诚实守信、严肃考纪、拒绝作弊

密　封　线

重庆大学《Fluid Mechanics》课程试卷

◉ A卷　○ B卷

2020 — 2021 学年　第 二 学期

开课学院：UC 联合　课程号：ME30811　考试日期：2021.7.28

考试方式：○ 开卷　◉ 闭卷　○ 其他　考试时间：120 分钟

题 号	一	二	三	四	五	六	七	八	九	十	总 分
得 分											

考试提示

1.严禁随身携带通讯工具等电子设备参加考试；

2.考试作弊，留校察看，毕业当年不授学位；请人代考、替他人考试、两次及以上作弊等，属严重作弊，开除学籍。

Introductions

You can have: 2 sides of a page equation sheet, calculator and writing utensil
- Write down all steps to get full credit
- Box your answer.

For all questions:

$\rho_{water} = 1.938 \frac{slug}{ft^3} = 1000 \frac{kg}{m^3}$

$\mu_{water} = 2.34\text{x}10^{-5} \frac{lbf \cdot s}{ft^2}$

$1 \frac{slug \cdot ft}{s^2} = 1\, lbf$

$g = 9.8 \frac{m}{s^2} = 32.2 \frac{ft}{s^2}$

5

1. A flat-bottomed barge (a flat-boat) having a 150 ft by 20 ft bottom is towed through still water at 10 mph.
   a. How long could the laminar portion of the boundary layer be, using critical Reynolds number of 537000? (in ft) [5 pts]

$L = 150 ft \quad w = 20 ft \quad V = 10mph = 10 \times 1.467 ft/s = 14.67 ft/s$

$(Re)_{critical} = \frac{\rho_{water} V L_{laminar}}{\mu_{water}} = 5.37 \times 10^5$

$\Rightarrow L_{laminar} = \frac{5.37 \times 10^5 \times \mu_{water}}{\rho_{water} \cdot V}$

$= \frac{5.37 \times 10^5 \times 2.34 \times 10^{-5}}{1.938 \times 14.67}$

$= 0.442 ft$

5

   b. What is the thickness of the laminar layer at its downstream end? (in ft) [5 pts]

$\frac{\delta}{L_{laminar}} = \frac{5.48}{\sqrt{(Re)_{critical}}}$

$\Rightarrow \delta = \frac{5.48 L_{laminar}}{\sqrt{(Re)_{critical}}}$

$= \frac{5.48 \times 0.442}{\sqrt{5.37 \times 10^5}}$

$\doteq \cancel{3.21}\ 3.3 \times 10^{-3}\ ft$

命题人：Pablo Mora　组题人：Pablo Mora　审题人：Thomas Huston　命题时间：2021.07　教务处制

c. What is the frictional drag force exerted by the water on the bottom of the barge? (in lbf) [10 pts]

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$$Re_L = \frac{\rho V L}{\mu} = \frac{1.938 \times 14.67 \times 150}{2.34 \times 10^{-5}} = 1.8225 \times 10^8$$

$$\cancel{C_D = \frac{0.0742}{Re_L^{1/5}} - \frac{1740}{Re_L} = 1.6424 \times 10^{-3}}$$

$\because Re_L > 10^7$ & $Re_L < 10^9$, $L_{laminar} = 0.44 ft \ll 150 ft$

$$\therefore C_D = \frac{0.455}{(\log Re_L)^{2.58}} = 1.8594 \times 10^{-3}$$

※: we can consider it as complete turbulent due to $L_{laminar}$ is very small

Hence, $F_D = C_D \cdot \frac{1}{2} \rho V^2 \cdot A$

$= 1.8594 \times 10^{-3} \times 0.5 \times 1.938 \times 14.67^2 \times 150 \times 20$

$= \cancel{1233.565}$ 1225.8247 lbf

d. What is the approximate thickness of the boundary layer at the rear end of the bottom of the barge? (in *ft*) [5 pts]

5

$$\frac{\delta_{rear}}{L} = \frac{0.382}{Re_L^{1/5}}$$

$$\Rightarrow \delta_{rear} = \frac{0.382 L}{Re_L^{1/5}}$$

$$= \frac{0.382 \times 150}{(1.8225 \times 10^8)^{1/5}}$$

$= 1.2765$ ft

2. A prototype airship is to operate at 20 m/s in air at standard conditions (i.e. ideal gas can be used). A model is constructed to 1/20 scale and tested in a pressurized wind tunnel, at 75 m/s, but at the same air temperature.

19 a) If the measured model drag force is 250 N, what will be the drag of the prototype? [19 pts]

6 b) What pressure should be used in the wind tunnel? (in Pa) [6 pts]

$$\frac{F}{\rho V^2 L^2} = f\left(\frac{\rho V L}{\mu}\right) \Rightarrow \frac{\rho_m \cdot V_m \cdot L_m}{\mu_m} = \frac{\rho_p \cdot V_p \cdot L_p}{\mu_p}$$

$$\Rightarrow \frac{\rho_m}{\rho_p} = \frac{V_p}{V_m} \cdot \frac{L_p}{L_m} \cdot \frac{\mu_m}{\mu_p} = \frac{20}{75} \times 20 \times 1 = 5.333$$

b) $\rho = \frac{p}{RT} \Rightarrow p_m = p_p \times \frac{\rho_m}{\rho_p} \times \frac{T_p}{T_m}$

$= 101 kPa \times 5.333 \times 1$

$= 5.39 \times 10^5 Pa$

a) $\frac{F_p}{\rho_p V_p^2 L_p^2} = \frac{F_m}{\rho_m V_m^2 L_m^2} \Rightarrow F_p = F_m \times \frac{\rho_p}{\rho_m} \times \left(\frac{V_p}{V_m}\right)^2 \times \left(\frac{L_p}{L_m}\right)^2$

$= 250 N \times \frac{1}{5.333} \times \left(\frac{20}{75}\right)^2 \times 20^2$

$= 1.333 kN$

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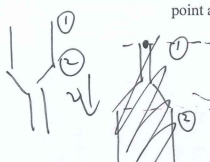
3. A 50-mm-diameter nozzle terminates a vertical 150-mm diameter pipeline in which water flows downward. At a point on the pipeline a pressure gage reads 276 kPa. If this point is 3.6 m above the nozzle tip and the head lost between point and tip is 1.5 m, calculate the flow rate. [25pts]



$g = 9.81\ m/s^2$, $\rho = 1000\ kg/m^3$

$d_1 = 150mm$, $h = 3.6m$, $d_2 = 50mm$, $h_L = 1.5m$

$p_{gage} = 276kPa$, $Q = ?$

Assume $\alpha_1 = \alpha_2 = 1$

$$\left(\frac{p_1}{\rho} + \alpha_1\frac{\bar{V}_1^2}{2} + gz_1\right) - \left(\frac{p_2}{\rho} + \alpha_2\frac{\bar{V}_2^2}{2} + gz_2\right) = gh_L$$

$p_{gage} = p_1 - p_2 = 276kPa$, $z_1 = h = 3.6m$, $z_2 = 0$.

$AR = \frac{A_2}{A_1} = \left(\frac{d_2}{d_1}\right)^2 = \left(\frac{50}{150}\right)^2 = \frac{1}{9}$

$\frac{A_2}{A_1} = \frac{\bar{V}_1}{\bar{V}_2} \rightarrow A_1\bar{V}_1 = A_2\bar{V}_2$

$\Rightarrow \cancel{\frac{p_{gage}}{\rho} + \frac{\bar{V}_1^2 - \bar{V}_2^2}{2} + gh = gh_L}$

$$\boxed{\Rightarrow \frac{p_{gage}}{\rho} + \frac{\bar{V}_2^2}{2}(AR^2 - 1) + gh = gh_L \qquad \Rightarrow \bar{V}_2 = \sqrt{\frac{2\left(gh_L - gh - \frac{p_{gage}}{\rho}\right)}{AR^2 - 1}}}$$

X

$\Rightarrow \cancel{\frac{\bar{V}_1^2 - \bar{V}_2^2}{2} - gh_L + gh = \frac{p_{gage}}{\rho}}$ $\quad \frac{V_1^2}{2}\left(1 - \frac{1}{AR^2}\right) = gh_L - gh + \frac{p_2 - p_1}{\rho}$

$\Rightarrow \cancel{\frac{\bar{V}_1^2}{2}\left(1 - \frac{1}{AR^2}\right) - gh_L + gh = \frac{p_{gage}}{\rho}}$ $\quad -4V_1^2 = g(h_L - h) - \frac{p_{gage}}{\rho}$

$\Rightarrow \cancel{\frac{\bar{V}_1^2}{2}\left(1 - \frac{1}{81}\right) - gh_L + gh = \frac{p_{gage}}{\rho}}$ $\quad V_1^2 = \frac{\frac{p_{gage}}{\rho} - g(h_L - h)}{4}$

$\Rightarrow \cancel{\frac{40}{81}V_1^2 - 9.81 \times 1.5 + 9.81 \times 3.6 = \frac{276 \times 10^3}{1000}}$

$\Rightarrow \bar{V}_1 = \cancel{22.74}\ 8.611\ m/s$, $Q = \bar{V}_1 \cdot A_1 = \bar{V}_1 \frac{1}{4}\pi d_1^2 = \cancel{22.74}\ 8.611 \times \frac{1}{4}\pi(150 \times 10^{-3})^2 = \cancel{0.4465}\ 0.1522\ m^3/s$

4. Fill-in the blank: [5 pts each]

Water flows in a pipeline. At station 1 in the line where the diameter is 7 in, the velocity is 12 ft/s and the pressure is 50 psi. At station 2, 40 ft away, the diameter reduces to 3 in.

At station 2:

5 i. The velocity is 65.33 ft/s.

5 ii. The pressure when the pipe is horizontal is ~~-14268.475~~ 22.2489 psi.

0 iii. The pressure when the pipe is vertical with flow downward is ~~-14260.53~~ psi. 31.1933

0 iv. The pressure when the pipe vertical with the flow upward is ~~-14278.42~~ psi. 13.3044

5 v. Explain why there is a difference in the pressure for the different situations: Due to the effect of "gh" and the flow direction. Even though the kinetic pressure is the same, "gh" decides the difference between the pressure.

①: $d_1 = 7in$, $V_1 = 12ft/s$, $p_1 = 50psi = 50 \times 144\ lbf/ft^2 = 7200\ lbf/ft^2$

②: $d_2 = 3in$

$L = 40ft$.

v. For ii, there is no effect of gh on pressure of ① & ②.
For iii, there is a pressure of gh belong to ① due to the direction is downward.
For iv, there is a pressure of gh belong to ② due to the direction is upward.

i. $V_1A_1 = V_2A_2$

$\Rightarrow V_2 = \frac{A_1}{A_2}V_1$

$= \left(\frac{d_1}{d_2}\right)^2 \cdot V_1$

$= \left(\frac{7}{3}\right)^2 \times 12$

$= 65.33\ ft/s$

iii. $p_1 + \frac{1}{2}\rho V_1^2 + gh = p_2 + \frac{1}{2}\rho V_2^2$

$\Rightarrow p_2 = p_1 + \frac{1}{2}\rho(V_1^2 - V_2^2) + gh$ $\quad 32.2 \times 40$

$= 7200 + \frac{1}{2} \times 1.938(12^2 - 65.33^2) + 9\cancel{81}$

$= 6425.9856\ lbf/ft^2$ $\cancel{-2053516.45\ lbf/ft^2}$

$= \cancel{44.625\ psi}$, $\cancel{-14260.53\ psi}$

$= 31.1933\ psi$

ii. $p_1 + \frac{1}{2}\rho V_1^2 = p_2 + \frac{1}{2}\rho V_2^2$

$\Rightarrow p_2 = p_1 + \frac{1}{2}1.938(V_1^2 - V_2^2)$

$= 7200 + \frac{1}{2} \times 1.938 \times (12^2 - 65.33^2)$

$= \cancel{-2054834.45\ lbf/ft^2}$

$= \cancel{-14269.475\ psi}$

$= 3203.8354\ lbf/ft^2$

$= 22.2489\ psi$

iv. $p_1 + \frac{1}{2}\rho V_1^2 = p_2 + \frac{1}{2}\rho V_2^2 + gh$

$\Rightarrow p_2 = p_1 + \frac{1}{2}\rho(V_1^2 - V_2^2) - gh$

$= 7200 + \frac{1}{2} \times 1.938 \times (12^2 - 65.33^2)$ $\quad 32.2 \times 40$

$= \cancel{-2054133\ lbf/ft^2}$

$= \cancel{-14264.8125\ psi}$

$= \cancel{-2056092.45\ lbf/ft^2}$

$= \cancel{-14278.429\ psi}$. $13.3044\ psi$