CVEN 311-501 (Socolofsky)

Fluid Dynamics

Exam #1: Introduction, fluid statics, and the Bernoulli equation
March 2, 2016, 7:00 p.m. – 8:40 p.m. in CE 118

Name: 

UIN: 

Instructions:

Fill in your name and UIN in the space above.

The exam is closed book, and only one double-sided sheet of notes is permitted. No collaboration with others!

For multiple choice questions, choose the single, best answer.

For short answer and workout problems, write down all steps necessary to solve the problem: show all your work. Failure to do so will result in a lower score. Be sure to answer all parts of all problems. Do not leave any problems blank.

Certification:

“An Aggie does not lie, cheat, or steal or tolerate those who do.” By my signature below, I certify that the work contained in this exam is my own and that I did not receive help from other students.

Signature: _________________________________ Date: _____________________
A. True or False (25 points)

For each of the following statements, check the box with the most appropriate response. For these problems, please refer to the apparatus in Figure 1; assume that all of the fluid in the figure is water and is not moving (hydrostatic condition).

1. \( p_A = 14.7 \) (psig)
   - [ ] True
   - [ ] False

2. \( p_C = 102.8 \) kPa (abs)
   - [ ] True
   - [ ] False

3. \( p_C = 0.21 \) (psig)
   - [ ] True
   - [ ] False

4. \( p_B < p_C \)
   - [ ] True
   - [ ] False

5. \( p_D = p_E \)
   - [ ] True
   - [ ] False

6. \( p_D > p_C \)
   - [ ] True
   - [ ] False

7. \( p_H = p_C \)
   - [ ] True
   - [ ] False

8. \( p_G = p_E \)
   - [ ] True
   - [ ] False

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Figure 1: Schematic of two beakers connected by a closed tube.
9. The gauge pressure at $F$ is negative
   □ True □ False

10. If the point $F$ is too high, the water there might boil
    □ True □ False

B. Multiple Choice (45 points)

For each of the following questions, circle the answer that is most appropriate or closest numerically to your answer. Be sure to clearly mark only one answer. Multiple selections will be graded as zero.

Figure 2 shows a schematic of one cup on a water wheel. The cup extends uniformly 40 cm into the page. Answer questions 1-5 about the forces acting in the cup and the torque on the water wheel axis.

![Figure 2: Schematic of one element on a water wheel.](image)

1. How large is the horizontal component of the resultant pressure force on wall $AB$ compared to that on wall $CD$?
   a. It is greater
   b. It is the same
   c. It is smaller
   d. There is no horizontal pressure force on wall $CD$
   e. None of the above

2. The hydrostatic pressure acting at point $B$ is
   a. 1.962 Pa
   b. 196.2 Pa
   c. 200 Pa
   d. 1962 Pa
   e. 19620 Pa
3. The magnitude of the resultant pressure force $F_R$ on wall $\overline{CD}$ is
   a. $7.85 \times 10^{-3}$ N
   b. 0.981 N
   c. 78.5 N
   d. 157 N
   e. 196 N

4. The resultant pressure force $F_R$ acting on wall $\overline{CD}$ is applied at a depth of
   a. 6.667 cm
   b. 10.000 cm
   c. 10.067 cm
   d. 13.333 cm
   e. 20.000 cm

5. The torque about the point A due to the water in the cup if $R = 2.5$ m is
   a. 0.634 Nm
   b. 70.6 Nm
   c. 634 Nm
   d. 693 Nm
   e. 732 Nm
Figure 3 shows a schematic of the viscous flow of water between two tanks of differing depths. The channel between the tanks is rectangular, with a depth $d$ and width $w$ into the page. Answer questions 6-9 about different aspects of this case.

Figure 3: Schematic of one flow between two tanks of different water levels.

6. If $h_m > 0$, then the pressure at $A$ is
   
   a. less than that at $B$
   b. equal to that at $B$
   c. greater than that at $B$
   d. $h_m$ is not related to the difference in pressure between $A$ and $B$
   e. None of the above

7. If $p_A = 85$ kPa and $h_m = 15$ cm, what is the pressure at $B$. The gauge fluid has a specific gravity of 13.6.
   
   a. -18.625 kPa
   b. 64.99 kPa
   c. 66.46 kPa
   d. 103.5 kPa
   e. 105.0 kPa
8. An equation for the velocity profile in the channel is given in the figure (note that \( y = 0 \) at the bottom of the channel). What is the shear stress at the bottom of the channel if \( p_A - p_B = 35 \text{ kPa} \)?
   a. 0
   b. 101.5 kPa
   c. 116.6 kPa
   d. 221.3 kPa
   e. None of the above

9. A hydroelectric turbine is installed between the points \( A \) and \( B \). What is the minimum pressure on the blades of the turbine above which cavitation will be prevented? Assume the water temperature is 20 °C (or 70 °F).
   a. 0.363 psia
   b. -14.337 psig
   c. 2340 Pa (gauge)
   d. -98985 Pa (abs)
   e. All of the above

A uniform rectangular relief gate \( AB \) is shown in Figure 4. The gate has a weight of 8000 lb, a width into the page of 4 ft, is pinned at \( A \), and rests on a rubber seal at \( B \). Answer the following question about this case.

10. The minimum water depth \( h \) within the canal needed to open the gate is closest to
   a. 3.21 ft
   b. 4.56 ft
   c. 5.63 ft
   d. 7.31 ft
   e. 9.08 ft
C. Workout Problem (30 points)

A pressurized water can that can be used as a fire extinguisher is shown in Figure 5. Assume the carbon dioxide gas in the head space of the tank acts as an ideal gas and the water as an ideal fluid.

Figure 5: Schematic of a pressurized water can.

1. What is the density (kg/m$^3$) of the carbon dioxide gas in the tank?
2. If the depth in the tank is 1.5 ft, what is the exit velocity at the end of the nozzle?

3. Ignoring drag, what is the maximum height \( h \) that the stream exiting the nozzle can reach?
D. Formulas and Fluid Properties

- Gravitational acceleration
  \[ g = 9.81 \text{ m/s}^2 = 32.17 \text{ ft/s}^2 \]  \hspace{1cm} (1)

- Atmospheric pressure
  \[ p_{atm} = 101,325 \text{ Pa} = 14.7 \text{ psia} \]  \hspace{1cm} (2)

- Absolute zero
  \[ T_{abs} = -273.15 \text{ K} = -459.67 \degree \text{R} \]  \hspace{1cm} (3)

- Vapor pressure of water at 20 °C (70 °F)
  \[ p_v = 2340 \text{ Pa} = 0.363 \text{ psia} \]  \hspace{1cm} (4)

- Hydrostatic pressure
  \[ p = p_0 + \rho gh \]  \hspace{1cm} (5)

- Forces on a plane surface
  \[ F_R = \gamma \sin \theta \int_A ydA = \gamma Ah_c \]
  \[ y_R = \frac{I_x}{y_c A} \]
  \[ I_x = I_{xc} + A y_c^2 \] \hspace{1cm} (6)

- Weight, specific weight, and specific gravity
  \[ W = \rho g V \]
  \[ \gamma = \rho g \]
  \[ SG = \frac{\rho}{\rho_{H_2O}} \] \hspace{1cm} (7)

- Viscosity and shear stress
  \[ \tau = \mu \frac{du}{dy} \] \hspace{1cm} (8)

- Bernoulli equation along a streamline
  \[ \frac{p}{\gamma} + \frac{v^2}{2g} + z = c \] \hspace{1cm} (9)

- Bernoulli equation normal to a streamline
  \[ \frac{p}{\gamma} + \int_{r_0}^{r} \frac{v^2}{gR} dn + z = c \] \hspace{1cm} (10)
Table 1: Physical properties of liquids at 101325 Pa and 20°C

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Density $\rho$ (kg/m$^3$)</th>
<th>Viscosity $\mu$ (N·s/m$^2$)</th>
<th>Surface Tension $\sigma$ (N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>726</td>
<td>$0.317\cdot10^{-3}$</td>
<td>0.0221</td>
</tr>
<tr>
<td>Glycerin</td>
<td>1260</td>
<td>1.50</td>
<td>0.0633</td>
</tr>
<tr>
<td>Mercury</td>
<td>13,550</td>
<td>$1.58\cdot10^{-3}$</td>
<td>0.466</td>
</tr>
<tr>
<td>Water</td>
<td>998.3</td>
<td>$1.00\cdot10^{-3}$</td>
<td>0.072</td>
</tr>
</tbody>
</table>

Table 2: Physical properties of liquids at 14.70 psia and 68°F

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Weight $\rho$ (lb/ft$^3$)</th>
<th>Viscosity $\mu$ (lb·s/ft$^2$)</th>
<th>Surface Tension $\sigma$ (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>45.4</td>
<td>$6.62\cdot10^{-6}$</td>
<td>0.00151</td>
</tr>
<tr>
<td>Glycerin</td>
<td>78.5</td>
<td>$31.3\cdot10^{-3}$</td>
<td>0.00434</td>
</tr>
<tr>
<td>Mercury</td>
<td>846</td>
<td>$33.0\cdot10^{-6}$</td>
<td>0.0319</td>
</tr>
<tr>
<td>Water</td>
<td>62.3</td>
<td>$20.2\cdot10^{-6}$</td>
<td>0.00492</td>
</tr>
</tbody>
</table>

Table 3: Properties of common gases

<table>
<thead>
<tr>
<th>Gas</th>
<th>Molecular Weight $M$ (g/mol)</th>
<th>Gas Constant (SI) $R$ (J/(kg·K))</th>
<th>Gas Constant (BG) $R$ (ft·lb/(slug·°R))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>35.34</td>
<td>286.9</td>
<td>1716</td>
</tr>
<tr>
<td>Oxygen</td>
<td>31.9988</td>
<td>259.8</td>
<td>1554</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>28.0134</td>
<td>296.8</td>
<td>1775</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>44.01</td>
<td>188.9</td>
<td>1130</td>
</tr>
<tr>
<td>Methane</td>
<td>16.043</td>
<td>518.3</td>
<td>3099</td>
</tr>
</tbody>
</table>
Figure 6: Areas and moments of inertia about the centroid of different plane shapes.

- For a rectangle with sides $b$ and $a$, the moments of inertia about the centroid are:
  
  $I_x = \frac{1}{12}ab^3 \quad A = ab$

  $I_y = \frac{1}{12}ab^3$

- For a circle with radius $R$, the moments of inertia about the centroid are:
  
  $I_x = \frac{1}{4}\pi R^4 \quad A = \pi R^2$

  $I_y = \frac{1}{4}\pi R^4$

- For a triangle with base $b$ and height $a$, the moments of inertia about the centroid are:
  
  $I_x = \frac{1}{36}ba^3 \quad A = \frac{1}{2}ab$

  $I_y = \frac{1}{36}ab^3$