# Unit 1 - Fluids Mechanics <br> Chapter 9 of your book. <br> <br> 1.1 Problems - Fluids \& Pressure <br> <br> 1.1 Problems - Fluids \& Pressure <br> Section 9.2 of your book. 

| Early E. C.: 11 |  |
| :---: | :---: |
| Total HW Points Unit 1: $\quad 18$ |  |
|  |  |
| Total Lab Points Unit 1: $\quad 22$ |  |
| Unit 1 Apps.: 15 <br> Late, Incomplete, V No Work, No |  |
|  |  |

1. In his original barometer, Pascal used water instead of mercury. Since water is less dense than mercury, the water barometer would have (a) a higher height than, (b) a lower height than, or (c) the same height as the mercury barometer. Explain your reasoning.

| Possible 1.1 Pts.: | $\mathbf{4}$ |  |
| :--- | ---: | ---: |
| Late, Incomplete, No work, |  |  |
| No Units Fee: | $-1-2$ | -3 |
| Final Score: | 4 |  |

2. In the previous problem, how high would the water column have been?
3. If you dive to a depth of 10.0 m below the surface of a lake, what is the pressure due to the water alone?
4. A $75.0-\mathrm{kg}$ athlete performs a single-handed handstand. If the area of his palm in contact with the floor is $125 \mathrm{~cm}^{2}$, what pressure (non-absolute) is exerted on the floor? What absolute pressure is exerted on the floor?

| Possible 1.2 Pts.: $\quad 4$ |  |
| :--- | ---: |
| Late, Incomplete, No work, |  |
| No Units Fee: | $-1-2-3$ |
| Final Score: | 4 |

1.2 Problems - Pascal's Law<br>Section 9.2 of your book.

1. The output piston of a hydraulic press has a cross sectional area of $0.25 \mathrm{~m}^{2}$. How much pressure on the input piston is required for the press to generate a force of 1.5 E 6 N ?
2. For the previous problem, what force is applied to the input piston if it has a diameter of 5.0 cm ?
3. A hydraulic lift in a garage has two pistons: a small one of cross sectional area $4.00 \mathrm{~cm}^{2}$ and a large one of cross-sectional area of $250 \mathrm{~cm}^{2}$. If this lift is designed to raise a $3500-\mathrm{kg}$ car, what minimum force must be applied to the small piston?
4. For the previous problem, if the force is applied through compressed air, what is the minimum air pressure applied to the small piston?

### 1.3 Problems - Buoyancy and Archimedes' Principle Section 9.3 of your book.

1. If the density of an object is exactly equal to the density of a fluid, the object will (a) float, (b) sink, (c) stay at any height in the fluid, as long as it's totally immersed. Explain yourself.
2. A cube 8.5 cm on each side has a mass of 0.65 kg . Will the cube float or sink in water? Prove your answer.
3. An object has a weight of 8.0 N in air. However, it apparently only weighs 4.0 N when it is completely submerged in water. What is the density of the object?
4. A steel cube 0.30 m on each side is suspended from a scale and immersed in water. What will the scale read? Assume a density of $7.8 \mathrm{E} 3 \mathrm{~kg} / \mathrm{m}^{3}$.

# 1.4 Problems - Fluid Dynamics <br> Section 9.4 of your book. Wizard Challenge Alert! 

1. If the radius of a pipe narrows to half its original size, will the flow speed in the narrow section (a) increase by a factor of 2 , (b) increase by a factor of 4 , (c) decrease by a factor of 4 ? Why?
2. If the radius of a pipe increases to three times its original size, what is the ratio of the flow speed in the wider section to that in the narrower section?
3. Water flowing through a wide horizontal tube is constricted to half the diameter. If the water speed is $1.5 \mathrm{~m} / \mathrm{s}$ in the larger part of the tube, by how much does the pressure drop in the constricted part? Express the final answer in atmospheres.
4. The speed of blood in a major artery of diameter 1.0 cm is $4.5 \mathrm{~cm} / \mathrm{s}$. What is the volume rate of flow in the artery?
5. For the previous question, if the capillary system has a total cross sectional area of $2500 \mathrm{~cm}^{2}$, the average speed of blood through the capillaries is what percentage of that through the major artery?
6. For the previous question, why must blood flow at low speed through the capillaries?

### 1.5 Problems - Bernoulli's Principle <br> \section*{Section 9.4 of your book.}

1. A vertical column of water in a pipe is allowed to emerge through two holes: A and B. If hole A is twice as far down the column as hole $B$, how much faster will water emerging from hole $A$ be traveling?
2. A 12 meter tall water-filled tube springs a leak 1.5 meters off the bottom.
A. What pressure is exerted by the water column at the point of the leak?
B. How fast does the water flow out of the hole?
3. A pump in the basement of a house supplies a pressure of 55 kPa to the water inside a 3.5 cm radius pipe. If the flow rate through the pump is $0.25 \mathrm{~m} / \mathrm{s}$, what is the volume flow rate of water out of a 2.0 cm radius nozzle in the bathroom 3.5 meters above the pump?

## AP Physics 2 <br> Unit 1.1 Lab - Buoyancy

Reminder: Update Table of Contents

Correction Credit:
Half

## Lab Overview:

Determine the buoyancy force acting on two solids.

Materials:
Cu OR Fe, \& Plastic Solids Construction Equipment
Triple Beam Balance

250 mL plastic Beaker
Paperclip Cradle Caliper Measuring Tool

## Mission 1: Densities of Metal and Plastic

Show all data, calculations, and notes you take for the following tasks in a tidy, well-organized data table. Use the calipers for all measurements. Use the caliper properly! Read page 14, or see me if needed.

Take data to calculate the volumes of the two objects: one metal (copper OR iron) and a plastic one. Also, record their masses. Calculate the densities of both, and include these in your data table.

Mission 2: Buoyancy Force
From data in Mission 1, calculate the expected $\mathrm{F}_{\mathrm{b}}$ of both substances. Record these in another table.

| Buoyancy Lab (1.1) Guide |  |  |
| :---: | :---: | :---: |
| Table of Contents, Title/Date, Detailed <br> Synopsis, Two Purposes | $/ 2$ |  |
|  | Data Table Present | $/ 1$ |
|  | Table Is Tidy | $/ 1$ |
|  | And Organized | $/ 1$ |
|  | Cu or Fe Density Data | $/ 1$ |
| Mission 2: <br> Buoyancy <br> Measurements | Plastic Density Data | $/ 1$ |
|  | Calculated Daoyancy | Free Points!!! |
|  | Apparent Mass | $/ 2$ |
| Analysis 1: Pressure and Force |  | /2 |
| Analysis 2: Free Body Diagram |  | $/ 2$ |
| Analysis 3: \% Error |  | $/ 1$ |
| Question 1: Error Mitigation |  | $/ 2$ |
| Question 2: Closeness of Buoyancies | $/ 2$ |  |
| Extra Credit: Identity of Plastic |  | +1 |
| Work Not Shown Fee: |  | $-1-2-3$ |
| Late Lab Fee: |  | -5 |
| Total: |  | $/ \mathbf{2 2}$ |

Make a cradle out of a paper clip, so that you can hang your metal mass from a construction equipment crane and suspend it in the water bath. You will have to tare the scale with the large black mass on the balance, THEN record the new 'apparent' mass of the cube, while the cube is completely submerged.

Analysis: 1 Point Each

1. Assuming that the top of your cube is exactly at 1.0 cm below the surface of the liquid, and that the cube is not at an angle with respect to the horizon, calculate the pressure of liquid on both the top and bottom faces. Then, calculate the difference in force acting on the different faces - this is the buoyancy force.
2. Make a well-labeled Free Body Diagram of your submerged metal cube from Mission 2, then use this to calculate the force of buoyancy acting on the cube.
3. Look up and report the density of your metal. Then, calculate the density percent error.

$$
\% \text { Error }=\frac{\mid \text { Accepted Value }- \text { Experimental Value } \mid}{\text { Accepted Value }} \times 100 \%
$$

Questions: 2 Points Each

1. What errors are present in this lab, and how could they be reduced?
2. How close were the three $\mathrm{F}_{\mathrm{b}}$ values (Mission 2 vs. Analysis 1 vs. Analysis 2) to each other? How would you expect the values to compare?
E. C. (+ 1 Point) Using density data and the internet, can you identify the clear plastic?

| AP Physics 2 | Unit 1-Fluid Dynamics |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Application Problems, AP Test Preparation Questions |  |  |  |  |  |
| Presentation <br> Points: | $/ 5$ | Late Fee: | -2 | Completion <br> (Booklet Check) | $/ 5$ |

Your grade on this problem set will depend on the presentation you provide for your problem, and whether they are complete when you submit your Booklet at the end of the Unit.

1. In a sample of seawater taken from an oil spill, an oil layer 4.0 cm thick floats on 55 cm of water. If the density of the oil is $0.75 \mathrm{E} 3 \mathrm{~kg} / \mathrm{m}^{3}$, what is the absolute pressure on the bottom of the container? Take the density of seawater to be $1.03 \mathrm{E} 3 \mathrm{~kg} / \mathrm{m}^{3}$.
2. During a plane flight, a passenger experiences ear pain due to a head cold that has clogged his Eustachian tubes. Assuming the pressure in his tubes remained at 1.00 atm (from sea level) and the cabin pressure is maintained at 0.900 atm , determine the air pressure force (including its direction) on one circular eardrum, assuming it has a diameter of 0.800 cm .
3. When a $0.80-\mathrm{kg}$ crown is submerged in water, its apparent weight is measured to be 7.3 N . Is the crown pure gold? The density of gold is $19.3 \mathrm{E} 3 \mathrm{~kg} / \mathrm{m}^{3}$.
4. The blood flow speed through an aorta with a radius of 1.00 cm is $0.265 \mathrm{~m} / \mathrm{s}$. If hardening of the arties causes the aorta to be constricted to a radius of 0.800 cm , by how much would the velocity increase?
5. The spout heights in the container in the figure are $10.0 \mathrm{~cm}, 20.0 \mathrm{~cm}, 30.0 \mathrm{~cm}$, and 40.0 cm . The water level is maintained at a $45-\mathrm{cm}$ height by an outside supply. What is the speed of the water out of each hole?


## Unit 1 Practice AP Multiple Choice Questions

The following problems (multiple choice and free response) are designed to train you to take the AP Physics 2 test in the spring, and will be scored at the end of the Unit - based on completion and accuracy.

1. A large tank is filled with water to a depth of 6 m . If Point $X$ is 1 m from the bottom and Point $Y$ is 2 m from the bottom, how does $\mathrm{p}_{\mathrm{x}}$, the hydrostatic pressure at Point X , compare to $\mathrm{p}_{\mathrm{y}}$, the hydrostatic pressure due to water at Point Y ?
a. $p_{x}=2 p_{y}$
b. $2 p_{x}=p_{y}$
c. $5 p_{x}=4 p_{y}$
d. $4 p_{x}=5 p_{y}$
e. $p_{x}=4 p_{y}$
2. The figure shows a closed container partially filled with liquid. Point Y is at a depth of 1 m , and Point Z is at a depth of 3 m . If the absolute pressure at Point Y is $13,000 \mathrm{~Pa}$, and the absolute pressure at Point Z is $29,000 \mathrm{~Pa}$, what is the pressure at the surface, Point X ?
a. $3,000 \mathrm{~Pa}$
b. $4,000 \mathrm{~Pa}$
c. 5,000 Pa
d. $7,000 \mathrm{~Pa}$
e. $8,000 \mathrm{~Pa}$

3. A plastic cube 0.5 m on each side and with a mass of 100 kg floats in water. What fraction of the cube's volume is above the surface of the water?
a. $1 / 5$
b. $1 / 4$
c. $1 / 2$
d. $3 / 4$
e. $4 / 5$
4. In the figure, a ball of specific gravity 0.4 and a volume $5 \mathrm{E}-3 \mathrm{~m}^{3}$ is attached to a string, the other end of which is fastened to the bottom of the tank. If the tank is filled with water, what is the tension in the string?
a. 20 N
b. 30 N
c. 40 N
d. 50 N
e. 70 N

5. An object of specific gravity 2 weighs 100 N less when it's weighed while completely submerged in water than when it's weighed in air. What is the actual weight of this object?
a. 200 N
b. 300 N
c. 400 N
d. 600 N
e. 800 N
6. In the pipe shown, which carries water, the flow speed at Point X is $6 \mathrm{~m} / \mathrm{s}$. What is the flow speed at Point Y ?
A. $2 / 3 \mathrm{~m} / \mathrm{s}$
B. $2 \mathrm{~m} / \mathrm{s}$
C. $4 \mathrm{~m} / \mathrm{s}$
D. $18 \mathrm{~m} / \mathrm{s}$
E. $54 \mathrm{~m} / \mathrm{s}$


## Unit 1 Example AP Question - Free Response

The experimental diving bell shown above is lowered from rest at the ocean's surface and reaches a maximum depth of 80 m . Initially it accelerates downward at a rate of $0.10 \mathrm{~m} / \mathrm{s}^{2}$ until it reaches a speed of $2.0 \mathrm{~m} / \mathrm{s}$, which then remains constant. During the descent, the pressure inside the bell remains constant at 1 atmosphere. The top of the bell has a cross-sectional area of 9.0 m . The density of seawater is $1025 \mathrm{~kg} / \mathrm{m}^{3}$.
(a) Calculate the total time it takes the bell to reach the maximum depth of 80 m .

(b) Calculate the weight of the water on the top of the bell when it is at the maximum depth.
(c) Calculate the absolute pressure on the top of the bell at the maximum depth.

On the top of the bell there is a circular hatch of radius $\mathrm{r}=0.25 \mathrm{~m}$.
(d) Calculate the minimum force necessary to lift open the hatch of the bell at the maximum depth.
(e) What could you do to reduce the force necessary to open the hatch at this depth? Justify your answer.

| AP Physics 2 |  | Unit 1 Review - Fluid Dynamics |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Points: | $I 18$ | Late or <br> Incomplete Fee: | $-2-4-6$ | Correction <br> Credit: | Final <br> Score: |  |

Solve these problems here, THEN enter your responses in the bubble sheet provided. Each question is worth two points.

1. A rectangular fish tank measuring 0.75 m by 0.50 m is filled with water to a height of 65 cm . What is the gauge pressure on the bottom of the tank?
A) $5,200 \mathrm{~Pa}$
B) $4,400 \mathrm{~Pa}$
C) $6,400 \mathrm{~Pa}$
D) $7,000 \mathrm{~Pa}$
E) $7,500 \mathrm{~Pa}$
2. To drink a soda (assume the same density as water) through a straw requires that you
 lower the pressure at the top of the straw.
What does the pressure need to be at the top of a straw that is 15.0 cm above the surface of the soda in order for the soda to reach your lips?
A) 9.95 E 4 Pa (absolute)
B) 7.62 E 4 Pa (absolute)
C) 8.43 E 4 Pa (absolute)
D) 1.02 E 5 Pa (absolute)
E) 1.12 E 5 Pa (absolute)
3. A rectangular boat of dimensions 0.30 m by 2.0 m by 4.5 m is overloaded such that the water level is just 1.0 cm below the top of the boat. What is the combined mass of the people and the boat? The top (height) of the boat is 0.30 m .
A) $2,140 \mathrm{~kg}$
B) $2,610 \mathrm{~kg}$
C) $2,900 \mathrm{~kg}$
D) $3,100 \mathrm{~kg}$
E) $3,500 \mathrm{~kg}$
4. A solid ball has a weight of 3.0 N . When it is submerged in water, it has an apparent weight of 2.7 N . What is the density of the ball?
A) $1,000 \mathrm{~kg} / \mathrm{m}^{3}$
B) $8,400 \mathrm{~kg} / \mathrm{m}^{3}$
C) $9,200 \mathrm{~kg} / \mathrm{m}^{3}$
D) $10,000 \mathrm{~kg} / \mathrm{m}^{3}$
E) $10,000 \mathrm{~kg} / \mathrm{m}^{3}$
5. A wood cube 0.30 m on each side has a density of $700 . \mathrm{kg} / \mathrm{m}^{3}$ and floats levelly in water. What is the distance from the top of the wood to the water surface?
A) 9.0 cm
B) 16.0 cm
C) 12.0 cm
D) 11.0 cm
E) 8.0 cm
6. For the previous problem, what mass has to be placed on top of the wood so that its top is just at the water level?
A) 6.3 kg
B) 8.1 kg
C) 9.2 kg
D) 9.9 kg
E) 11.1 kg
7. An aquarium is filled with a liquid. A cork cube, 10.0 m on a side, is pushed and held at rest completely submerged in the liquid. It takes a force of 7.84 N to hold it under the liquid. If the density of cork is $200 . \mathrm{kg} / \mathrm{m}^{3}$, find the density of the liquid.
A) $980 \mathrm{~kg} / \mathrm{m}^{3}$
B) $1200 \mathrm{~kg} / \mathrm{m}^{3}$
C) $1000 \mathrm{~kg} / \mathrm{m}^{3}$
D) $1150 \mathrm{~kg} / \mathrm{m}^{3}$
E) $750 \mathrm{~kg} / \mathrm{m}^{3}$
8. An ideal fluid is moving at $3.0 \mathrm{~m} / \mathrm{s}$ in a section of a pipe of radius 0.20 m . If the radius in another section is 0.35 m , what is the flow speed there?
A) $0.76 \mathrm{~m} / \mathrm{s}$
B) $0.88 \mathrm{~m} / \mathrm{s}$
C) $0.98 \mathrm{~m} / \mathrm{s}$
D) $1.2 \mathrm{~m} / \mathrm{s}$
E) $1.5 \mathrm{~m} / \mathrm{s}$
9. A pump is used to send water through a pipe of radius 10.0 cm , and the water exits through a nozzle of radius 1.0 cm at an elevation 1.0 m higher than the pump. If the water flows through the 10.0 cm pipe at $0.4 \mathrm{~m} / \mathrm{s}$, what is the gauge pressure of water at the pump?
A) 108 kPa
B) 260 kPa
C) 400 kPa
D) 760 kPa
E) 810 kPa
