Midterm of Fluid Mechanics
AQS110 Programme of Fisheries and Aquaculture

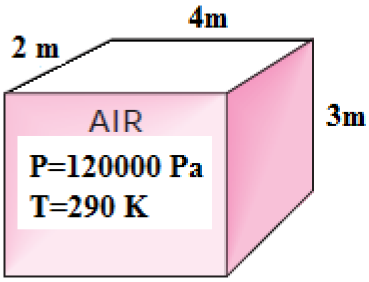
Name and Surname: Number: Signature

(The books are opened. The values not given in the exam will be chosen by you. There are 10 questions. Each question is 10 points.)

1- A cubic meter of air at an absolute pressure of 100000 Pa is compressed isentropically to 0.5 m^3 by the tire pump, k=1.4. What is the final pressure?

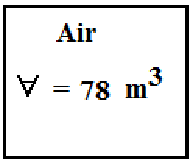
2- A jet aircraft flies at a speed of 400 km/h at an altitude of 11000 m, where the temperature is 216 K and the specific heat ratio is k= 1.4. Determine the ratio of the speed of the aircraft, V, to that of the speed of sound, c, at the specified altitude using isentropic process. The gas constant of air is R=286.9 kJ/kg K.

3- Determine the density, specific gravity, and mass of the air in a room whose dimensions are $2 \times 3 \times 4\ m$ at 120000 Pa and 290 K. The gas constant of air is R=286.9 kJ/kg K. The density of water is $\rho = 1000\ kg/m^3$.

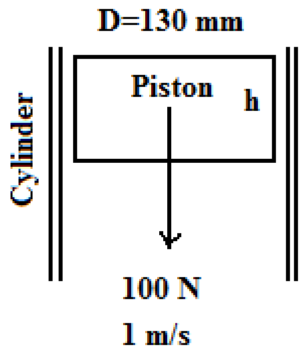


4- A plastic tank that has a volume of 0.4 m^3 is filled with water. The mass of the tank is 5 kg. The weight of the combined system is to be determined. The density of water is given to be ρ= 1000 kg/m^3.

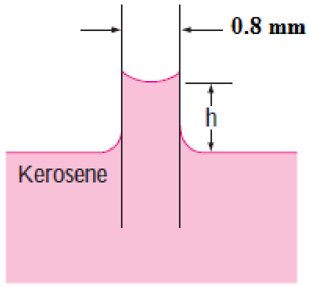
5- Determine the mass and the weight of the air contained in a room whose volume is 78 m^3. Assume the density of the air is 1.16 kg/m^3



6- A piston of weight 100 N slides in a lubricated pipe at a speed of 1 m/s, as shown in Fig. The clearance between piston and pipe is 0.3 mm. The diameter and height of piston are 130 mm and 150 mm, respectively. What is the viscosity of the oil?



7- A 0.8 mm diameter glass tube is inserted into kerosene at 20 °C. The contact angle of kerosene with a glass surface is 26°. Determine the capillary rise of kerosene in the tube in Fig. The surface tension of kerosene-glass at 20 °C , $\sigma = 0.028\ N/m$. The density of kerosene is 820.1 kg/m^3.



8- A 2-mm-diameter tube is inserted into an unknown liquid whose density is 950 kg/m^3, and it is observed that the liquid rises 6 mm in the tube, making a contact angle of 16°. Determine the surface tension of the liquid.

9- What is a Newtonian fluid? Is water a Newtonian fluid?

10- What is surface tension? What is it caused by? Why is the surface tension also called surface energy?

Prof. Dr. Metin GÜNER

Midterm of Fluid Mechanics for Programme of Fisheries and Aquaculture

SOLUTIONS

April 2017

Name and Surname: Number: Signature

(The books are opened. The values not given in the exam will be chosen by you. There are 10 questions. Each question is 10 points.)

1- A cubic meter of air at an absolute pressure of 100000 Pa is compressed isentropically to 0.5 m^3 by the tire pump, k=1.4. What is the final pressure?

Solution: For an isentropic compression

$$\frac{P_0}{\rho_0^k} = \frac{P}{\rho^k} \rightarrow P = \frac{\rho^k}{\rho_0^k} P_0 = (\frac{\rho}{\rho_0})^k P_0$$

As the volume, is reduced by one-half, the density must double, since the mass $m = \rho\forall$, of the gas remains constant. Thus with k= 1.40 for air

$$P = (2)^{1.4} \times 100000 = 263901.5 \text{ Pa}$$

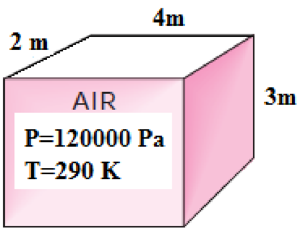
2- A jet aircraft flies at a speed of 400 km/h at an altitude of 11000 m, where the temperature is 216 K and the specific heat ratio is k= 1.4. Determine the ratio of the speed of the aircraft, V, to that of the speed of sound, c, at the specified altitude using isentropic process. The gas constant of air is R=286.9 kJ/kg K.

Solution: Undergoing an isentropic process, the speed of sound can be calculated as

$$c = \sqrt{kRT} = \sqrt{1.4 \times 286.9 \times 216} = 294.5\ m/s$$

$Ma = \frac{V}{c} = \frac{400/3.6}{294.5} = 0.377$ The flow is said to be subsonic (Ma<1)

3- Determine the density, specific gravity, and mass of the air in a room whose dimensions are $2 \times 3 \times 4\ m$ at 120000 Pa and 290 K. The gas constant of air is R=286.9 kJ/kg K. The density of water is $\rho = 1000\ kg/m^3$.



Solution: At specified conditions, air can be treated as an ideal gas. The gas constant of air is R=286.9 kJ/kg K.

$$\rho = \frac{P}{RT} = \frac{120\ 000\ Pa}{286.9 \frac{kJ}{kgK} \times 290\ K} = 1.442\ kg/m^3$$

The specific gravity of air becomes

$$SG = \frac{\rho}{\rho_{H_2O\ at\ 4\,°C}} = \frac{1.442}{1000} = 0.001442$$

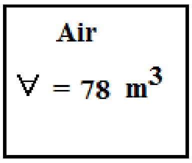
Finally, the volume and the mass of air are
$\forall = 2 \times 3 \times 4 = 24\ m^3 \quad m = \rho\forall = 1.442 \times 24 = 34.608\ kg$

4- A plastic tank that has a volume of 0.4 m^3 is filled with water. The mass of the tank is 5 kg. The weight of the combined system is to be determined. The density of water is given to be ρ= 1000 kg/m^3.

Solution:
$m_w = \rho\forall = 1000 \times 0.4 = 400\ kg \quad m_{tot} = m_w + m_{tank} = 400 + 5 = 45\ kg$

Thus $W = mg = 45\ \times 9.81 = 441.45\ N$

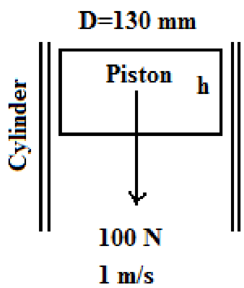
5- Determine the mass and the weight of the air contained in a room whose volume is 78 m^3. Assume the density of the air is 1.16 kg/m^3



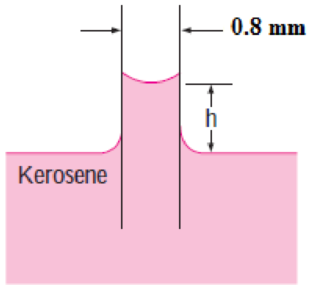
Solution: The mass and weight of the air in the room are to be determined. The density of air is constant throughout the room. The density of air is given to be ρ= 1.16 kg/m^3.
$m = \rho\forall = 1.16 \times 78 = 90.48\ kg$
$W = mg = 90.48 \times 9.81 = 887.61\ N$

6- A piston of weight 100 N slides in a lubricated pipe at a speed of 1 m/s, as shown in Fig. The clearance between piston and pipe is 0.3 mm. The diameter and height of piston are 130 mm and 150 mm, respectively. What is the viscosity of the oil?

Solution:
$\tau = \mu\frac{du}{dy} = \mu\left(\frac{v}{y}\right) \quad \mu = \tau\frac{y}{v} = \frac{F}{A}\frac{y}{v} = \frac{100\times0.0003}{\pi\times0.130\times0.150\times1} = 0.4897\ Pas$



7- A 0.8 mm diameter glass tube is inserted into kerosene at 20 °C. The contact angle of kerosene with a glass surface is 26°. Determine the capillary rise of kerosene in the tube in Fig. The surface tension of kerosene-glass at 20 °C , $\sigma = 0.028\ N/m$. The density of kerosene is 820.1 kg/m^3.



Solution: There are no impurities in the kerosene, and no contamination on the surfaces of the glass tube. The kerosene is open to the atmospheric air. The contact angle of kerosene with the glass surface is given to be 26°.

Capillary rise in tube: $h = \frac{2\sigma cos\theta}{\rho g R} = \frac{2\times0.028\times cos26}{8045\times0.0004} = 0.0156\ m = 15.6\ mm$

8- A 2-mm-diameter tube is inserted into an unknown liquid whose density is 950 kg/m^3, and it is observed that the liquid rises 6 mm in the tube, making a contact angle of 16°. Determine the surface tension of the liquid.

Solution: $\sigma = \frac{\rho g R h}{2cos\theta} = \frac{950\times9.81\times0.001\times0.006}{2cos16} = 0.029\ N/m$

9- What is a Newtonian fluid? Is water a Newtonian fluid?

Solution: Fluids whose shear stress is linearly proportional to the velocity gradient (shear strain) are called *Newtonian fluids*. Most common fluids such as water, air, gasoline, and oils are Newtonian fluids.

10- What is surface tension? What is it caused by? Why is the surface tension also called surface energy?

Solution: The magnitude of the pulling force at the surface of a liquid per unit length is called *surface tension* σ_s. It is caused by the attractive forces between the molecules. The surface tension is also surface energy (per unit area) since it represents the stretching work that needs to be done to increase the surface area of the liquid by a unit amount. Surface tension is the cause of some very interesting phenomena such as capillary rise and insects that can walk on water.

Prof. Dr. Metin GÜNER

Final Exam of Fluid Mechanics
AQS110 Programme of Fisheries and Aquaculture

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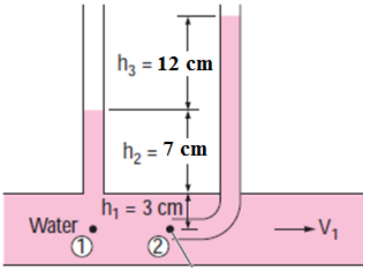
(The books are opened. The values not given in the exam will be chosen by you. There are 10 questions. Each question is 10 points.)

1. Heated air at 1 atm and 35°C is to be transported in a 150-m-long circular plastic duct at a velocity of 6.6 m/s. Determine the major loss and pressure drop of the duct. The the friction factor, *f*, is 0.018.The density, dynamic viscosity, and kinematic viscosity of air at 35°C are ρ=1.145 kg/m^3, μ=1.895×10^5 kg/m.s, and ν=1.655×10^{-5} m^2/s.

2. A Newtonian fluid with a dynamic or absolute viscosity of 0.38 Ns/m^2 and a density of 900 kg/m^3 flows through a 25 mm diameter pipe with a velocity of 3 m/s. Determine the type of flow

3. A piezometer and a Pitot tube are tapped into a horizontal water pipe, as shown in Figure to measure static and stagnation (static + dynamic) pressures. For the indicated water column heights, determine the velocity at the center of the pipe. The flow is steady and incompressible.



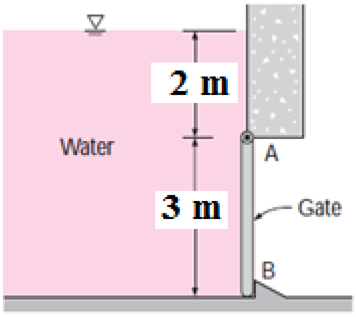
4-Please write the Bernoulli equation form that states the sum of the pressure head, the velocity head, and the elevation head is constant along a streamline.

5. What is the temperature at 1000 m above the earth's surface? The temperature at sea level (z=0) is T_a =15 °C, the lapse rate (the rate of change of temperature with elevation) is $\beta = 0.00650\ K/m$.

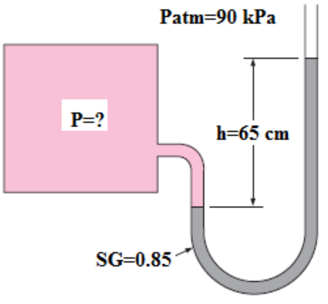
6- A 20-cm-diameter, 60-cm-high vertical cylindrical container is partially filled with 50-cm-high liquid whose density is 850 kg/m^3. The cylinder is rotated at a constant speed. Determine the rotational speed at which the liquid will start spilling from the edges of the container.

7. The volume of a body completely immersed in water is 0.5 m^3 and the specific weight of water is 9810 N/m^3. What is the buoyant force exerted by water to the body?

8. A 3-m-high, 6-m-wide rectangular gate is hinged at the top edge at *A* and is restrained by a fixed ridge at *B*. Determine the hydrostatic force exerted on the gate by the 5-m-high water .



9. A manometer is used to measure the pressure in a tank. The fluid used has a specific gravity of 0.85, and the manometer column height is 65 cm, as shown in Figure. If the local atmospheric pressure is 90 kPa, determine the absolute pressure within the tank.



10. Determine the absolute pressure exerted on a diver at 30 m below the free surface of the sea. Assume a barometric pressure of 101 kPa and a specific gravity of 1.03 for seawater.

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Final Exam of Fluid Mechanics
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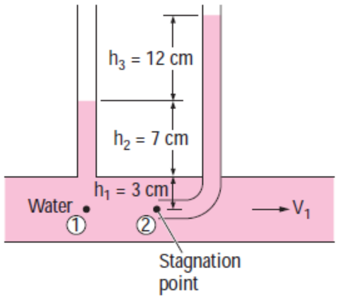
$$h_L = f\frac{l}{D}\frac{V^2}{2g} = 0.018\frac{150\times 6.6^2}{0.26\times 2\times 9.81} = 23.06\,m \quad \Delta P = h_L\gamma = 23.06\times 1.145\times 9.81 = 259\,Pa$$

2. A Newtonian fluid with a dynamic or absolute viscosity of *0.38 Ns/m²* and a density of *900 kg/m³* flows through a *25 mm* diameter pipe with a velocity of 3 *m/s*. Determine *a)* type of flow

$$Re = \frac{\rho VD}{\mu} = \frac{900\times 3\times 0.025}{0.38} = 177.6$$ The flow type is laminar because of Re=177.6<2100

3. A piezometer and a Pitot tube are tapped into a horizontal water pipe, as shown in Figure to measure static and stagnation (static + dynamic) pressures. For the indicated water column heights, determine the velocity at the center of the pipe. The flow is steady and incompressible.

$$V_1 = \sqrt{2\times g\times h_3} = \sqrt{2\times 9.81\times 0.12} = 1.53\,m/s$$



4-Please write the Bernoulli equation form that states the sum of the pressure head, the velocity head, and the elevation head is constant along a streamline.

$$\frac{P}{\gamma} + \frac{V^2}{2g} + z = constant$$

$\frac{P}{\gamma}$ →The pressure term is called the ***pressure head*** and represents the height of a column of the fluid that is needed to produce the pressure *p*.

$\frac{V^2}{2g}$ →The velocity term, is the ***velocity head*** and represents the vertical distance needed for the fluid to fall freely (neglecting friction) if it is to reach velocity *V* from rest.

z →The elevation term is related to the potential energy of the particle and is called the ***elevation head.***

5. What is the temperature at 1000 m above the earth's surface? The temperature at sea level (z=0) is T_a =15 $°C$, the lapse rate (the rate of change of temperature with elevation) is $\beta =$ $0.00650\ K/m.$

$$T = T_a - \beta\ z = (273 + 15) + 0.0065 \times 1000 = 294.5\ K = 21.5\ °C$$

6- A 20-cm-diameter, 60-cm-high vertical cylindrical container, shown in Fig., is partially filled with 50-cm-high liquid whose density is 850 kg/m^3. Now the cylinder is rotated at a constant speed. Determine the rotational speed at which the liquid will start spilling from the edges of the container. The increase in the rotational speed is very slow so that the liquid in the container always acts as a rigid body. The bottom surface of the container remains covered with liquid during rotation (no dry spots).

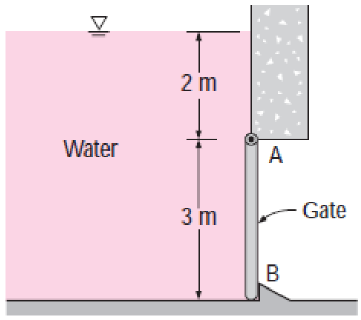
$$z = \frac{r^2\omega^2}{2g} + constant \quad 0.20 = \frac{0.1^2(\frac{2\pi n}{60})}{2\times 9.81} + 0 \rightarrow n = 189\ rpm$$

7. The volume of a body completely immersed in water is 0.5 m^3 and the specific weight of water is 9810 N/m^3. What is the buoyant force exerted by water to the body?

$$F_B = \gamma\forall = 9810 \times 0.5 = 4905\ N$$

8. A 3-m-high, 6-m-wide rectangular gate is hinged at the top edge at *A* and is restrained by a fixed ridge at *B*. Determine the hydrostatic force exerted on the gate by the 5-m-high water .

$F_R = P_{ave}A = \rho g h_C A = 1000\times9.81\times3.5\times3\times6 = 206010$ N



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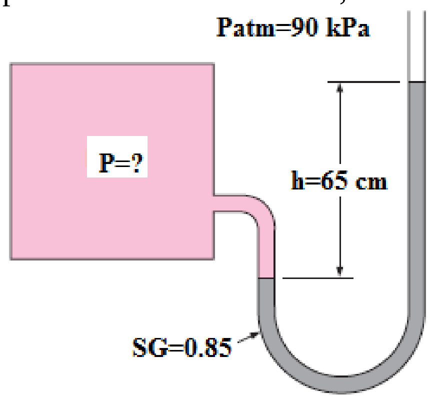

$$P = \rho gh + P_{atm} = 0.85 \times 1000 \times 9.81 \times 0.65 + 90\,000 = 95420\ Pa$$

10. Determine the absolute pressure exerted on a diver at 30 m below the free surface of the sea. Assume a barometric pressure of 101 kPa and a specific gravity of 1.03 for seawater.

$$P_{abs} = \rho gh + P_{atm} = 1.03 \times 9810 \times 30 + 101000 = 404129\ Pa$$