ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

MID Semester Examination
Course No.: ME 4411
Course Title: Fluid Mechanics-I

Summer Semester: A.Y. 2022-2023
Time: 1.5 Hours
Full Marks: 75

There are **03 (Three)** Questions. Answer all of them. Marks in the margin indicate full marks. Do not write on this question paper. Symbols carry their usual meanings. Assume reasonable values for any missing data. Programmable calculators are not allowed.

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1. (a) Using Newton's law of viscosity, *identify* the effects of temperature on the viscosity of liquid and gases. **[05]** CO2, PO2 K2

(b) *Formulate* the way of calculating the buoyant force acting on a body of uniform density immersed in a fluid. **[05]** CO2, PO2 K3, P1

(c) *Analyze* the stability of (a) a submerged and (b) a floating body whose center of gravity is above the center of buoyancy. **[05]** CO2, PO2 K4, P1

2. (a) An elderly woman is rushed to the hospital because she is having a heart attack. The emergency room doctor informs her that she needs immediate coronary artery (a vessel that wraps around the heart) bypass surgery because one coronary artery has 75 percent blockage (caused by atherosclerotic plaque). This surgery involves using an artificial graft (typically made of Dacron) to divert blood from the coronary artery around the blockage and reattach to the coronary artery beyond the blockage site. The coronary artery diameter is $\mathbf{D_1}$ mm and its length is $\mathbf{L_1}$ mm. The bypass graft diameter is $\mathbf{D_2}$ mm and its length is $\mathbf{L_2}$ mm. The flow rate within the bypass graft is **Q** l/s. Blood has a density of $\boldsymbol{\rho}$ kg/m^3 and a dynamic viscosity of $\boldsymbol{\mu}$ centipoise. Assume that the Dacron and coronary artery have different material properties and friction factor. **[10]** CO3, PO3 K5, P1, P2

Based on the above case, *establish* the relationship between viscosity and the shear stress developed in artificial graft that will meet the same type of flow in coronary artery. Will the blood flow will follow the Newton's Law of Viscosity or not? Please explain.

(b) Consider the top surface of a flat plate of arbitrary shape completely submerged in a liquid. The plane of this surface intersects the horizontal free surface at angle **θ**, and take the line of intersection to be the *x*-axis. The absolute pressure above the liquid is $\boldsymbol{P_0}$, which is the local atmospheric pressure $\boldsymbol{P_{atm}}$ if the liquid is open to the atmosphere (but $\boldsymbol{P_0}$ may be different than $\boldsymbol{P_{atm}}$ if the space above the liquid is evacuated or pressurized). **[10]** CO3, PO3 K5, P1, P2

Based on the above case, develop an equation for the resultant hydrostatic force acting on the surface in a homogeneous (constant density) fluid which is equal to the product of the pressure **Pc** at the centroid of the surface and the area **A** of the surface. Also calculate the line of action considering a flat plate completely submerged in a liquid.

(c) Consider an elementary regular fluid parallelopiped with sides **dx**, **dy** and **dz**. The velocity components in **x**, **y** and **z** directions are **u**, **v**, **w** respectively. Let **ρ** be the density of the fluid within the parallelopiped. The conservation of mass theory suggested that mass of water within the parallelopiped is neither created nor destroyed. **[10]** CO3, PO3 K5, P1, P2

Based on the above case, develop the unsteady continuity equation for compressible flow in three-dimensional case. Will the equation be applicable to incompressible flow? Please explain.

3. (a) RMS Titanic sank in the early morning of 15 April 1912 in the North Atlantic Ocean, four days into the ship's maiden voyage from Southampton to New York City. The largest ocean liner in service at the time, Titanic had an estimated 2,224 people on board including *Jack Dawson* and *Rose De Witt Bukater*. When she struck an iceberg at around 23:40 (ship's time) on Sunday, 14 April 1912. Her sinking two hours and forty minutes later at 02:20 (ship's time; 05:18 GMT) on Monday, 15 April, resulted in the deaths of more than 1,500 people, making it one of history's deadliest marine disasters during peacetime. Recently, a sonar study of the bow of the Titanic on the ocean floor has revealed that the holes caused by the iceberg are much smaller than originally thought. **[10]** CO4, PO4 K8, P1, P3

Until this study, it was assumed that a large, 100 m long gash was ripped in the Titanic's side, but now the sonar reveals that the area of the hole was only 1.4 m^2 (the size of a typical door) as shown in **Fig.1**. The hole of the Titanic was approximately 6.1 m below sea level at the start of the sinking. Was the hole large enough to sink the Titanic in 160 minutes? The dimensions of the ship were-length 269 m, maximum width 28 m, and height 30.5 m.

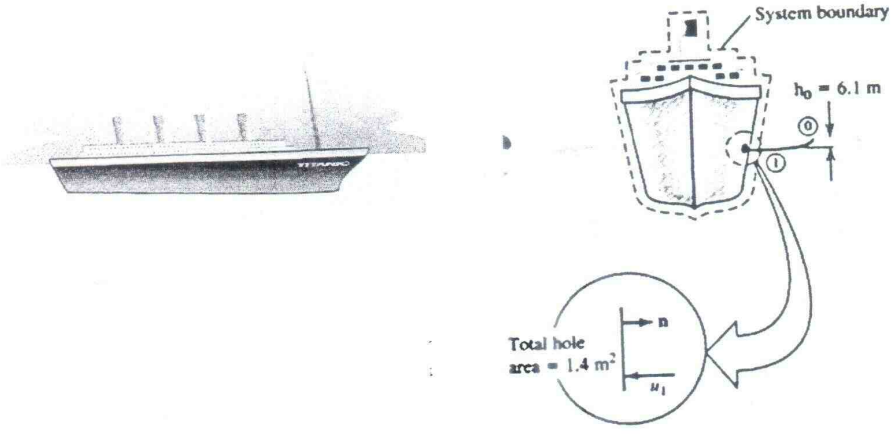

Figure 1

(b) A water reservoir, A, whose free-surface is kept at a pressure of $2x10^5$ Pa above the atmospheric pressure, discharges to another reservoir, B, open to the atmosphere shown in **Fig. 2**. The water free-surface level at the second reservoir is 0.5 m above the pressurized reservoir A. Neglect the energy dissipation in the connecting duct between the two reservoirs. The connecting duct has constant diameter. **[10]** CO4, PO4 K8, P1, P3

(a). Compute the water velocity in the connecting duct. Would the velocity at the duct exit change if the diameter of the connecting duct is not constant?

(b). What would be the pressure difference between the duct inlet and outlet if the duct is horizontal and of constant diameter?

(c). The pressure in the duct is imposed by which of the two reservoirs?