University of Eswatini

Final Examination, August 2020

B.Sc IV, BASS IV, BEd IV

Title of Paper : Fluid Mechanics

Course Code : MAT456/M455

Time Allowed : Three (3) Hours

Instructions

1. This paper consists of TWO sections.

   a. **SECTION A(COMPULSORY): 40 MARKS**
   Answer ALL QUESTIONS.

   b. **SECTION B: 60 MARKS**
   Answer ANY THREE questions.
   Submit solutions to ONLY THREE questions in Section B.

2. Each question in Section B is worth 20%.

3. Show all your working.

4. Special requirements: None.

THIS PAPER SHOULD NOT BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR.

SECTION A: ANSWER ALL QUESTIONS

Question 1

(a) Define the following terms:

(i) Natural flow, viscocity, Non-Newtonian fluid, incompressible flow. [8]

(ii) Describe the Eulerian and Lagrangian methods of describing fluid motion. [4]

(iii) Show that in a two dimensional incompressible steady flow field the equation of continuity is satsisfied with the velocity components in rectangular coordinates given by

$$u = \frac{k(x^2 - y^2)}{(x^2 + y^2)^2}, \quad v = \frac{2xy}{(x^2 + y^2)^2}$$ where k is arbitrary constant. [4]

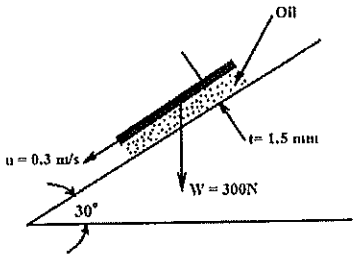
(b) (i) Give the physical significance implied in the equation of continuity in fluid motion. [4]

(ii) For a certain two-dimensional flow field the velocity is given by the equation $(x^2 - y^2)\mathbf{i} - 2xy\mathbf{j}$. Is the flow irrotational? [4]

(iii) Show that $\phi = (x - t)(y - t)$ represents the velocity potential of an incompressible two dimensional fluid. [5]

(iv) The velocity components in a three-dimensional flow field for an incompressible fluid are $(2x, -y, -z)$. Is it a possible field? Determine the equations of the stream line passing through the point (1,1,1). [5]

(v) Calculate the dynamic viscosity of an oil which is used for lubrication between a square plate of size $0.8m \times 0.8m$ and an inclined plane with an angle of inclination 30^0 as shown in the figure. The weight of a square plate is $300N$ and it slides down in the inclined plane with a uniform velocity of $0.3m/s$. Thickness of the oil film is $1.5mm$. [6]



SECTION B: ANSWER ANY 3 QUESTIONS

Question 2

(a) Derive Bernoulli's equation for nonviscous, incompressible, steady flow and the forces acting are due to pressure and gravity. [10]

(b) The wind in a hurricane reaches 200 km/h. Estimate the force of the wind on a window facing the wind in a high-rise building if the window measures $1m \times 2m$. Use the density of the air to be $1.2kg/m^3$. [10]

Question 3

(a) A velocity field in a plane flow is given by $V = 2yt\mathbf{i} + x\mathbf{j}$. Find the angular velocity and the vorticity vector at the point $(4m, 2m)$ at $t = 3s$. [10]

(b) A jet of water 8 cm in diameter impinges on a plate normal to its axis. For a velocity of 4 m/s, what force will keep the plate in equilibrium? [10]

Question 4

(a) Determine the acceleration of a fluid particle from the following flow field: $\mathbf{q} = \mathbf{i}(Axy^2t) + \mathbf{j}(Bx^2yt) + \mathbf{k}(Cxyz)$. [10]

(b) Consider the velocity field given by $q = (1 + At)\mathbf{i} + x\mathbf{j}$. Find the equation equation of the streamline at $t = t_0$ passing through the point (x_0, y_0). Also obtain the equation of the pathline of a fluid element which comes to (x_0, y_0) at $t = t_0$. Show that, if $A = 0$ (i.e. steady flow), the streamline and pathlines coincide. [10]

Question 5

(a) (i) What is(are) the advantage(s) of dimensional analysis. [3]

(ii) State the principle of dimensional homogeneity [3]

(b) A pipe A $450mm$ in diameter branches into two pipes B and C of diameters $300mm$ and $200mm$ respectively. If the average velocity in $450mm$ diameter pipe is $3m/s$, find

(i) Discharge through $450mm$ diameter pipe. [7]

(ii) Velocity in $200mm$ diameter pipe if the average velocity in $300mm$ pipe is $2.5m/s$. [7]

Question 6

(a) From the law of conservation of mass, show that whether the flow field represented by $u = -3x + y^2 - \frac{1}{x}$ and $v = x^2 + 3xy + y\ln x$ is a possible velocity field for two dimensional incompressible flow. [6]

(b) Show that for an incompressible steady flow with constant viscosity, the velocity components

$$u(y) = y\frac{U}{h} + \frac{h^2}{2\mu}\left(-\frac{dp}{dx}\right)\frac{y}{h}\left(1 - \frac{y}{h}\right)$$
$$v = w = 0$$

satisfy the equation of motion, when the body force is neglected. $h, U, dp/dx$ are constants and $p = p(x)$.

Hint: Apply Navier-Stokes equation. [14]

End of Examination Paper