I D NO.

PRESIDENCY UNIVERSITY, BENGALURU

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Weightage: 40% | Max Marks: 80 | Max Time: 2 hrs. | 09 May, Wednesday, 2018

END TERM FINAL EXAMINATION MAY 2018 **SET A**

Even Semester 2017-18 | Course: **MEC 203 Fluid Mechanics and Machines** | IV Sem Mechanical

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Instructions:

(i) Answer all the questions.
(ii) Write neatly and legibly.

Part A

(12 M + 8 M + 8 M = 28 Marks)

1. Consider a fluid entering a pipe at constant velocity. Explain the development of the velocity boundary layer in the pipe with a neat sketch. Your explanation and sketch must cover the following: the average velocity of the flow, the velocity boundary layer, the irrotational (core) flow region, the hydrodynamic entrance region, the hydrodynamic fully developed region, the developing velocity profile and the fully developed velocity profile.

2. Air enters the diffuser shown in Figure 1 with a velocity of 165 m/s. It is known that the ratio of specific heats of air is 1.4 and that its gas constant $R = 287$ J/kg·K.

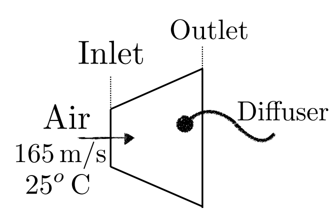

Figure 1: Air Flowing Through a Diffuser

(a) Determine the speed of sound at 25^o C and the Mach number at the inlet of the diffuser.

(b) Classify the flow as subsonic, sonic, supersonic or hypersonic with a reason.

(c) Distinguish between a nozzle and a diffuser based on inlet and outlet air speeds.

(d) State whether the speed of air at the outlet of the diffuser is slower, faster or equal to its speed at the inlet.

3. Are the statements in (a) thru (d) true or false? Argue your claim in each case.

(a) Internal flow is driven by gravity while external flow is driven by pressure difference.

(b) The centrifugal pump is an energy absorbing device.

(c) A flow dominated by viscous forces and not by inertial forces is a laminar flow.

(d) We always prefer analytical solutions to computational ones in fluid flow problems.

Part B

(11 M + 17 M = 28 Marks)

4. A fluid is flowing in a 2-mm diameter pipe at an average velocity of 1.2 m/s. The density and viscosity of the fluid are 1000 kg/m^3 and 1.6×10^{-3} kg/m·s, respectively. Answer the following questions assuming the flow is steady and that the length of the pipe is 8 m.

(a) Determine the Reynolds number and classify the flow as laminar, transitional or turbulent based on your answer.

(b) Determine the pressure drop and head loss in the pipe.

(c) Determine the pumping power required to overcome this pressure drop.

5. This question will cover the part of the course related to fluid machinery.

(a) Distinguish between energy absorbing and energy producing devices.

(b) Is it correct to say that the purpose of a turbine is to extract energy from a fluid resulting in a reduction in its pressure and *necessarily* resulting in a reduction in its speed across the turbine? If it is wrong to say so, then correct this statement..

(c) What is a turbomachine? Give one example of an energy absorbing turbomachine and one example of an energy producing turbomachine.

(d) The following questions test your knowledge of the pelton wheel turbine.

i. Is the flow of water radial, tangential or axial in the pelton wheel turbine? Is this an impulse or a reaction turbine? Does it operate under a "high" or a "low" head?

ii. Sketch the pelton wheel turbine showing its parts, like the runner, buckets, nozzle, casing, penstock and the flow control needle. Explain the function and construction of these parts.

iii. Explain the "working principle" of the pelton wheel turbine.

Part C

(12 M + 12 M = 24 Marks)

6. This question tests you on the equation of linear momentum for fully developed, steady, laminar flow of an incompressible fluid in a pipe.

(a) Draw a free body diagram and perform a force balance on the ring shaped differential element in Figure 2 to derive the equation of linear momentum, viz.,

$$r\frac{dP}{dx} + \frac{d}{dr}(\tau r) = 0.$$

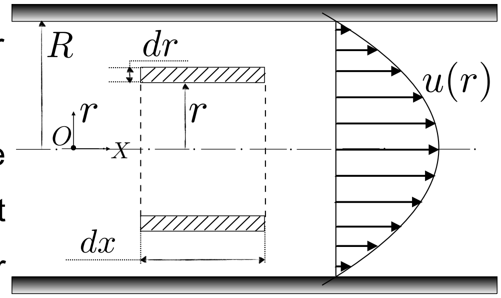

Figure 2: A Ring Shaped Differential Element in a Fluid Flowing in a Pipe

(b) Assuming the fluid in the pipe is Newtonian make an appropriate modification to the shear stress τ in terms of the velocity gradient $\frac{du}{dr}$.

7. A scaled down model of a car was tested in a wind tunnel to study the forces exerted on its windshield. In this problem we consider the readings from a sensor located at a point on its windshield. The direction of the pressure force $P \cdot dA$ and the shear force $\tau_w \cdot dA$ acting at the point B are shown in Figure 3.

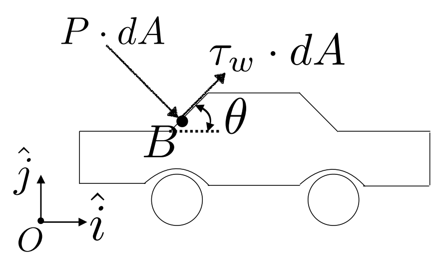

Figure 3: Pressure and Shear Forces Acting at a Point B on a Car

The sensor measures the pressure and shear forces to be 100 N and 40 N, respectively. The windshield makes an angle $\theta = 45^o$ with respect to the horizontal. Answer the following questions based on this information.

NOTE: Your final answers representing forces in vector notation should be in terms of the unit vectors $\hat{i}$ and $\hat{j}$ only. If you decide to introduce other unit vectors, you must transform all vectors in terms of the $\hat{i}$ and $\hat{j}$ unit vectors in your final answers.

(a) Write down the horizontal component of the shear force in vector notation.

(b) Write down the vertical component of the pressure force in vector notation.

(c) Write down the drag, lift and resultant forces acting at the point B in vector notation. What are the magnitudes and directions of these forces?

The End

PRESIDENCY UNIVERSITY, BENGALURU

SCHOOL OF ENGINEERING

Weightage: 40% Max Marks: 80 Max Time: 2 hrs. 09 May, Wed, 2018

SOLUTIONS TO THE END TERM FINAL EXAMINATION MAY 2018 **SET A**

Even Semester 2017-18 Course: **MEC 203 Fluid Mechanics and Machines** IV Sem Mechanical

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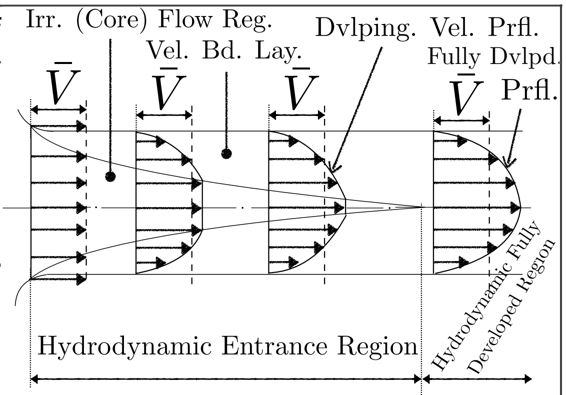
Part A

(12 M + 8 M + 8 M = 28 Marks)

Solution to Q. 1	Figure 1 shows the development of the velocity boundary layer in laminar flow in a pipe from the entrance of the pipe when the fluid is viscous. An explanation of Figure 1 is as follows. 1. The average velocity of the flow is shown as $\bar{V}$ in the figure. This remains the same at all cross sections in the pipe. 2. The velocity boundary layer is the region in which shear stresses are present due to viscosity.  Figure 1: The Development of the Velocity Boundary Layer in a Pipe 3. The irrotational (core) flow region has negligible friction effects and a constant velocity profile. 4. The velocity boundary layer gets thicker from the entrance and eventually “meets” the centerline. This phenomenon explains the developing velocity profile and the fully developed velocity profile shown in the figure. 5. The region from the entrance to this “meeting point” is called the hydrodynamic entrance region. 6. The flow after this “meeting point” is “fully developed” and is called the hydrodynamic fully developed region.
Scheme of Marking	✦ Explanation of each point - 1 M ✦ Each of the six points shown in Figure 1 - 1 M
L. O. No.	(vi)
Max Time	15 minutes

Solution to Q. 2	(a) The speed of sound at the conditions given is $c = \sqrt{kRT} = \sqrt{1.4 \cdot 287 \cdot (273 + 25)} \approx 346$ m/s. The Mach number at the inlet to the diffuser is Ma $= \frac{165}{346} \approx 0.48.$ (b) The flow is subsonic because the Mach number Ma $\approx 0.48 < 1.$ (c) Flow is accelerated in an nozzle. Therefore, the air speed at the outlet of a nozzle is faster than the air speed at its inlet. A diffuser, on the other hand, is used to decelerate flow. Therefore, the air speed at the outlet of a diffuser is slower than the air speed at its inlet. (d) From (c) we conclude that the air speed at the outlet of the diffuser in Figure 1 is lower than 165 m/s.
Scheme of Marking	Note: Evaluators may choose to deduct to a maximum of half a mark for incorrect units in the entire solution to this problem. ✦ Formulas - 2M, Final answers - 2 M ✦ Classifying the flow - 1 M ✦ Nozzles accelerate flow - 1 M, Diffusers decelerate flow - 1 M, ✦ Saying that the air speed at the outlet of the diffuser is lower - 1 M
L. O. No.	(viii)
Max Time	15 minutes
Solution to Q. 3	(a) False! Internal flow is driven by pressure difference while external flow is driven by gravity. (b) True! A centrifugal pump absorbs energy to raise the pressure of a fluid. (c) True! Flows dominated by viscous forces have low Reynolds numbers which correspond to laminar flows. (d) True! Analytical solutions are exact while computational solutions are approximate.
Scheme of Marking	✦ Correct truth value - 1 M ✦ Correct explanation - 1 M
L. O. No.	(vi), (vii) and (ix)
Max Time	10 minutes

Part B

(11 M + 17 M = 28 Marks)

Solution to Q. 4	(a) The Reynolds number of the flow is $\mathscr{R}e = \frac{\rho \bar{V} D}{\mu} = \frac{1000 \cdot 1.2 \cdot 0.002}{1.6 \times 10{-}3} = 1500.$ Since this Reynolds number $\mathscr{R}e < 2300$ the flow is laminar. (b) The pressure drop in the pipe is $\Delta P = \frac{8\mu L\bar{V}}{R^2} = \frac{8 \cdot 1.6 \times 10^{-3} \cdot 8 \cdot 1.2}{0.001^2} = 1{,}22{,}880$ Pa. The head loss corresponding to this loss in pressure is $h_L = \frac{\Delta P}{\rho g} = \frac{1{,}22880}{1000 \cdot 9.81} \approx 12.53$ m.

Solution to Q. 4 Continues	The loss in pressure can also be calculated using $\Delta P = f \dfrac{L}{D} \dfrac{\rho \bar{V}^2}{2}$ where the Darcy friction factor $f = \dfrac{64}{\mathscr{Re}}$. This formula also gives us $\Delta P = \dfrac{64}{1500} \cdot \dfrac{8}{0.002} \cdot \dfrac{1000 \cdot 1.2^2}{2} = 1{,}22{,}880$ Pa. We get the same head loss $h_L = 12.53$ m. (c) The pumping power required to overcome the loss in pressure of $\Delta P = 1{,}22{,}880$ Pa is given by $\dot{W}_{\text{pump}} = \bar{V} \cdot (\pi R^2) \cdot \Delta P = 1.2 \cdot (\pi \cdot 0.001^2) \cdot 122880 \approx 0.46$ W.
Scheme of Marking	<u>Note</u>: Evaluators may choose to deduct to a maximum of half a mark for incorrect units in the entire solution to this problem. ✦ Correctly expressing the pipe diameter in meters - 1 M ✦ Each formula - 1M, final answers - 1 M ✦ Classifying the flow - 1 M, giving the correct reason for it - 1 M
L. O. No.	(vi)
Max Time	15 minutes
Solution to Q. 5	(a) A fluid machine is called an <u>energy absorbing device</u> when energy is supplied to this machine and it transfers most of this energy to a fluid, usually via a rotating shaft. The increase in energy of the fluid is usually felt as an increase in pressure of the fluid. An <u>energy producing device</u> extracts energy from a fluid and transfers most of this energy to some form of mechanical energy output, usually as a rotating shaft. (b) It is incorrect to say so. A correct statement would be: The purpose of a turbine is to extract energy from a fluid resulting in a reduction in its pressure and <u>not *necessarily*</u> resulting in a reduction in its speed across the turbine. (c) Pumps and turbines in which energy is supplied or extracted by a rotating shaft is called a turbomachine. A centrifugal pump is an example of an energy absorbing turbomachine. A wind turbine is an example of an energy producing turbomachine. (d) The answers to this part of the question are as follows. (i) The pelton wheel turbine is a tangential flow, impulse turbine that usually operates under a high head. (ii) The construction of a pelton wheel turbine is shown in Figure 2. We now discuss each of the parts. - The <u>runner</u> is a disc which has blades or buckets or Pelton cups attached to its rim. - The <u>buckets</u> on the runner are hemispherical in shape. The impact of water on the buckets makes the runner rotate.

Solution to Q. 5 Continues

- The nozzle is a circular guide mechanism which guides the water to flow in a desired direction.
- The casing made of cast iron or alloy steel provides safety against accidents.
- The penstock is a pipe through which water with high potential energy from a reservoir.
- A needle regulates the flow through the nozzle.

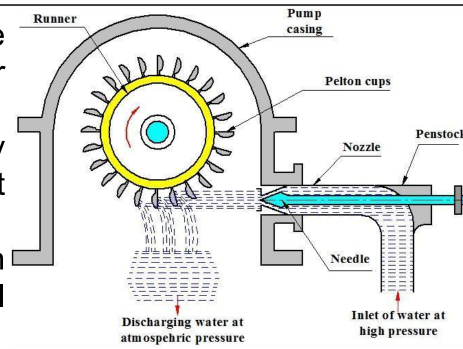


Figure 2: The Construction of a Pelton Wheel Turbine

(iii) The working principle of the pelton turbine is explained as follows. The nozzle increases the kinetic energy of water from the inlet to outlet. This water hits the buckets on the runner causing the runner rotate. This rotation is caused due to the "impulse action" of the water.

Scheme of Marking

- ✦ Energy absorbing device - 1 M, energy producing device - 1 M
- ✦ Stating the statement in (b) is wrong and correcting it - 1 M
- ✦ Definition of turbomachinery - 1 M, Two examples - 1 M
- ✦ Answer to (d)-(i) - 1 M
- ✦ Sketch of the turbine showing all the six parts listed in the question - 3 M
- ✦ Explanation of the six parts - 6 M
- ✦ Explanation of the working principle of the pelton wheel turbine - 2 M

L. O. No.	(ix)
Max Time	20 minutes

Part C

(12 M + 12 M = 24 Marks)

Solution to Q. 6 (a)

Figure 3 shows the free body diagram of the differential element suggested in the question. Since the flow is steady the acceleration of the element along the $X-$ axis is zero. Therefore, Newton's

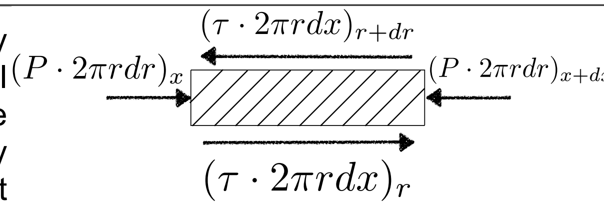


Figure 3: Free Body Diagram of the Ring Shaped Differential Element Given in the Question

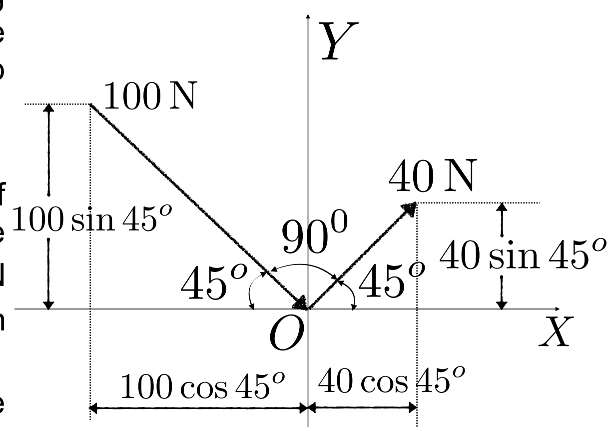
second law reduces to $\Sigma F_X = 0$. Applying this law to the element gives us $(P \cdot 2\pi r dr)_x - (P \cdot 2\pi r dr)_{x+dx} + (\tau \cdot 2\pi r dx)_r - (\tau \cdot 2\pi r dx)_{r+dr} = 0$. We rewrite this as follows

$P_x \cdot 2\pi r dr - P_{x+dx} \cdot 2\pi r dr + (\tau r)_r \cdot 2\pi dx - (\tau r)_{r+dr} \cdot 2\pi dx = 0$,

$(P_x - P_{x+dx}) 2\pi r dr + [(\tau r)_r - (\tau r)_{r+dr}] 2\pi dx = 0$.

Dividing this by $2\pi dr dx$ gives us $r \dfrac{P_x - P_{x+dx}}{dx} + \dfrac{(\tau r)_r - (\tau r)_{r+dr}}{dr} = 0$,

$-r \dfrac{dP}{dx} - \dfrac{d(\tau r)}{dr} = 0$, and then we get $r \dfrac{dP}{dx} + \dfrac{d(\tau r)}{dr} = 0$. This is the equation of linear momentum for fully developed, steady, laminar flow of a viscous fluid in a pipe.

Solution to Q. 6 (b)	For a Newtonian fluid we have $\tau = \mu \frac{du}{dr}$. We know $\frac{du}{dr} < 0$ from $u(r)$. So we must write $\tau = -\mu \frac{du}{dr}$ in the equation of linear momentum we have derived in (a). Doing this gives us $r\frac{dP}{dx} + \frac{d}{dr}(\mu r \frac{du}{dr}) = 0$. We can go a step further by assuming the viscosity μ of the fluid in the pipe is constant to get $r\frac{dP}{dx} + \mu \frac{d}{dr}(r\frac{du}{dr}) = 0$.
Scheme of Marking	✦ Each force on the free body diagram - 1 M ✦ Referring to Newton's second law with or without acceleration - 1 M ✦ Applying the law to the element to get the first equation - 2 M ✦ Reducing this first equation to the one given in the question - 2 M ✦ Mathematical relation for a Newtonian fluid - 1 M ✦ Having the right sign in the relation for Newtonian fluids - 1 M ✦ Final equation even without "going a step further" - 1 M
L. O. No.	(vi)
Max Time	20 minutes
Solution to Q. 7	Figure 4 shows the forces acting on the windshield with the information necessary to help resolve the forces along the $X-$ and $Y-$axis. (a) The horizontal component of the shear force acting on the windshield is $40\cos 45^{o}$ N ≈ 28.3 N. In vector notation we write it as $70.7\hat{i}$. (b) The vertical component of the pressure force in vector notation is $-100\sin 45\hat{j} \approx -70.7\hat{j}$.  Figure 4: The Forces Acting on the Windshield of the Car (c) The forces in vector notation are: $\overrightarrow{F}_{\text{drag}} = (70.7 + 28.3)\hat{i} = 99\hat{i}$, $\overrightarrow{F}_{\text{lift}} = (-70.7 + 28.3)\hat{j} = -42.4\hat{j}$, $\overrightarrow{F}_{\text{resultant}} = 99\hat{i} - 42.4\hat{j}$. The magnitudes of these forces are $\mid \overrightarrow{F}_{\text{drag}} \mid = 99$ N, $\mid \overrightarrow{F}_{\text{lift}} \mid = 42.4$ N and $\mid \overrightarrow{F}_{\text{resultant}} \mid = \sqrt{99^2 + (-42.4)^2} \approx 107.7$ N. The directions of these forces are as follows. The drag force acts along the $X-$axis in the positive direction, the lift force acts along the $Y-$axis in the negative direction, and the resultant force acts at an angle $\tan^{-1}(-\frac{42.4}{99}) \approx -23.2^{o}$ with respect to the $X-$axis.

Scheme of Marking	✦ A sketch that may not be as detailed as Figure 4 but something to show that the student is considering angles and resolving forces - 1 M ✦ Each quantity - 1 M
L. O. No.	(viii)
Max Time	20 minutes

The End

ID NO:	

PRESIDENCY UNIVERSITY, BENGALURU

SCHOOL OF ENGINEERING

Weightage: 20%   Max Marks: 40   Max Time: 1 hr.   28 March Wednesday 2018

TEST – 2   **SET A**

Even Semester 2017-18 Course: **MEC 203 Fluid mechanics and Machines**   IV Sem. Mechanical

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Instruction:

(i) Read the question properly and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) Scientific and Non-programmable calculators are permitted
(iv) Answer briefly

Part A

(2 Q x 6 M = 12 Marks)

1. Systems like particles and rigid bodies obey the law of conservation of mass, Newton's laws of motion and the laws of thermodynamics. Write down the equations corresponding to such laws and explain each equation in one sentence. Which theorem "adapts" these laws to apply to control volumes?

2. A garden hose attached to the nozzle is used to fill a bucket of 0.9385 m^3. The inner diameter of the hose is 3 cm which reduces to 0.8cm at the exit of the nozzle. Assume it takes 30 seconds to fill the bucket. (a) Determine volume flow rate (b) mass flow rate of water through the hose. (c) Determine average velocity of water at nozzle exit.

Part B

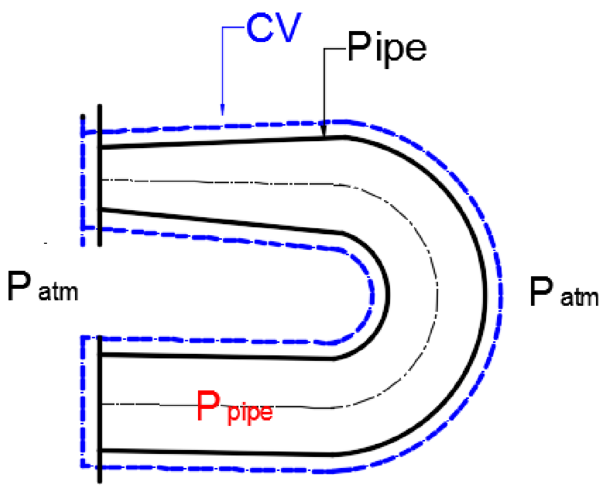
(1Q x 10 M = 10 Marks)

3. Derive the linear momentum equation in 1-d for a control volume considering the integral equation of a fluid flow using the schematic diagram.

Part C

(3Q x 6 M = 18 Marks)

4. A reducing elbow is used to deflect the water flow at a rate of 20 kg/s in a horizontal pipe 180° while accelerating it. The elbow discharges water into the atmosphere. The cross section area of the elbow is 80 cm^2 at the inlet and 7 cm^2 at the outlet. The elevation difference between inlet and outlet is 50 cm. Neglect weight of the elbow and the water in it. (a) Determine gauge pressure at the inlet of the elbow. (b) Find the anchoring force needed to keep the elbow in its place.



180° bend pipe

5. Derive the equation of energy using Reynolds transport theorem by using the suitable parameters and schematic diagram

6. The pump of a water distribution system is powered by 20kW electric motor who's efficiency is 85%. The water flow rate through the Pipe is 15 litre per second. The diameter of the inlet and outlet pipe are same and elevation difference across the pump is negligible. Assume the pressure at the inlet and outlet of the pipe is 50 kpa and 100 kpa respectively. Determine (a) The temperature rise of water from the inlet to outlet of the pump. (b) The mechanical efficiency of the pump.

PRESIDENCY UNIVERSITY, BENGALURU

SCHOOL OF ENGINEERING

Weightage: 20% | Max Marks: 40 | Max Time: 1 Hour | Tuesday, Feb 20, 2018

TEST – 1

Even Semester 2017-18 | Course: **MEC 203 Fluid Mechanics and Machines** | IV Sem Mechanical

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Instructions

(i) Answer all the questions in Parts A and B. <u>Answer any three questions in Part C!!</u>
(ii) You have sixty minutes to answer the test. Plan your test!
(iii) It is your duty to make your work understood to the evaluator of your test. Write neatly!
(iv) Freehand drawings are encouraged to save you time.
(v) You will need to use non-programmable calculators to answer this test.

Part A (Answer all questions!)

(6 M + 4 M + 4 M = 14 Marks)

1. Distinguish between solids and fluids using the Mohr's circle. Keep your answer brief.
2. Explain the concept of fluid as a continuum using density as an example.
3. Define and give the units of each of the following thermodynamic properties of fluids.

   (a) Pressure (b) Density (c) Temperature

   State the mathematical expression relating these properties for a perfect gas.

Part B (Answer all questions!)

(2 Q x 4 M = 8 Marks)

4. Derive an expression for the change in height h in a circular tube of radius R containing a liquid with surface tension γ and contact angle θ as shown in Figure 1. Assume the liquid has constant density ρ and it is acted on by the acceleration due to gravity g.

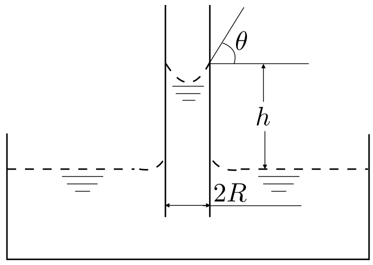

Figure 1: Capillary Rise

5. Figure 1 shows a fluid flowing between two plates. The bottom plate is fixed while the top one moves with a constant velocity V m/s. Assume pressure does not vary along the X-axis, the flow is not accelerating, the fluid is newtonian and the shear stress is constant throughout. Obtain a mathematical expression for velocity u as a function of y, i. e., obtain $u(y)$.

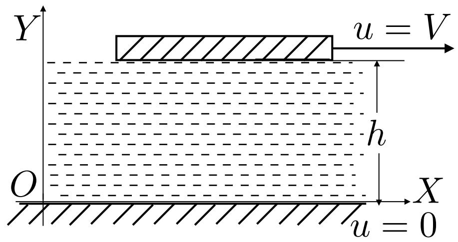

Figure 2: Viscous Flow between Flat Plates

Part C (Answer any three of the four questions!)

(3 Q x 6 M = 18 Marks)

6. Figure 3 shows water stored in a dam. Take the acceleration due to gravity as $9.81\ \mathrm{m/s^2}$.
   (i) Determine the magnitudes of the horizontal and vertical point forces acting on the wall of the dam. What is the resultant force?
   (ii) Locate the point of action of the horizontal force from the free surface.

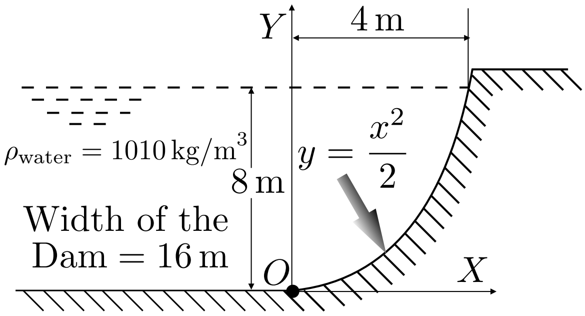

Figure 3: Water Stored in a Dam

7. Figure 4 shows a rectangular block in water.
   (i) What is the depth of immersion of the block in water? Assume $g = 9.81\ \mathrm{m/s^2}$.
   (ii) Determine the height of the centre of gravity and the point of action of the force of buoyancy from the bottom face of the block.
   (iii) Determine the height of the metacenter from the bottom of the block.
   (iv) Is the block stable to tilts by "small angles" in the front view?

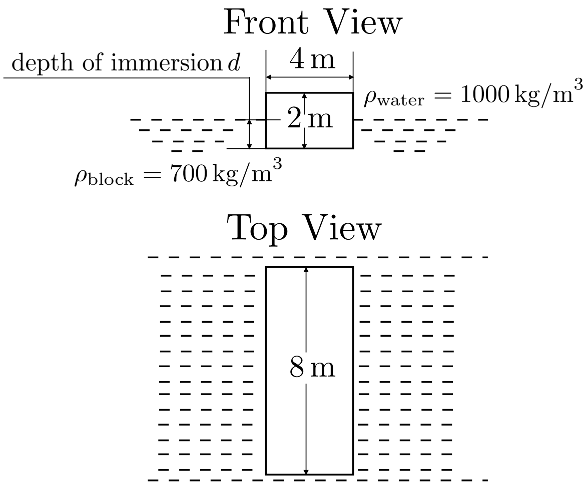

Figure 4: A Rectangular Block in Water

8. A cup of sugared tea placed in a truck is shown in Figure 5. The figure also shows the directions of the acceleration of the truck $a_x = 3\ \mathrm{m/s^2}$ and the acceleration due to gravity $g = 9.81\ \mathrm{m/s^2}$. These accelerations can be assumed to be constant.
   (i) For the dimensions of the cup and height of the tea in the cup determine if the tea spills out of the cup. If the tea does not spill out of the cup, sketch a figure showing how the tea rearranges itself in the cup.
   (ii) Find the pressure at the point P when the truck is in motion.

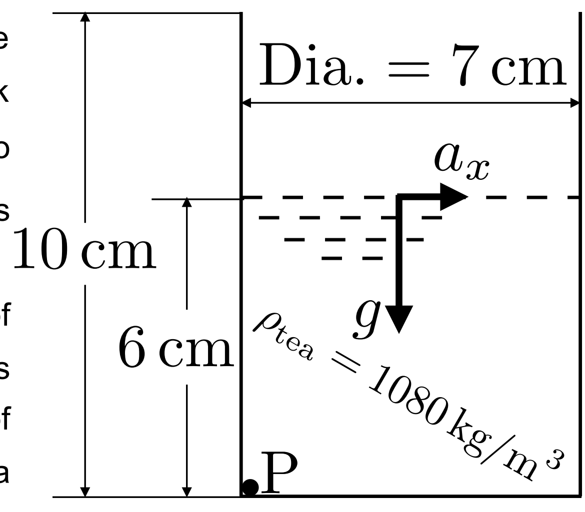

Figure 5: Sugared Tea in a Cup Placed in a Moving Truck

9. The velocity field in m/s in a flowing fluid is given by $\overrightarrow{V}(x,y) = x\hat{\imath} + y\hat{\jmath}$.
   (i) Determine all the stagnation points in the flow.
   (ii) Determine the magnitude and direction of the velocity vector at the point (1,1). Sketch this velocity vector showing its components along the horizontal and vertical directions.
   (iii) Determine the acceleration vector $\overrightarrow{a}(x,y)$. What are the magnitudes and directions of the local acceleration and the convective acceleration?