KEMENTERIAN PENGAJIAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

POLITEKNIK MALAYSIA

HYDROSTATIC FORCE MASTERY

PRACTICAL EXAMPLES FOR STUDENTS

There are no secrets to success. It is the result of preparation, hard work and learning from failure.
-Colin Powell-

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Preface

Alhamdulillah, praise to Allah SWT, with His grace and mercy, the First Edition of e-book Hydrostatic Force Mastery: Practical Examples for Students has finally completed. We hope that this e-book will be helpful as a guideline in their learning process. This e-book is developed as a guide and reference for lecturers also. Special thanks also to those who were directly or indirectly involved in the completion of this e-book. Any positive feedback mostly welcomed and appreciated.

Abstract

"Hydrostatic Force Mastery: Practical Examples for Students" is a detailed guide designed to help students grasp the principles of hydrostatics through hands-on examples and practical applications. This book breaks down complex theories into easy-to-understand segments, featuring step-by-step explanations and illustrative exercises. The chapter focuses on different aspects of hydrostatic forces, providing readers with a solid foundation in both theoretical knowledge and practical skills. Ideal for engineering students, this resource aims to enhance learning and mastery of hydrostatics, preparing students for real-world challenges and advanced studies in hydraulics.

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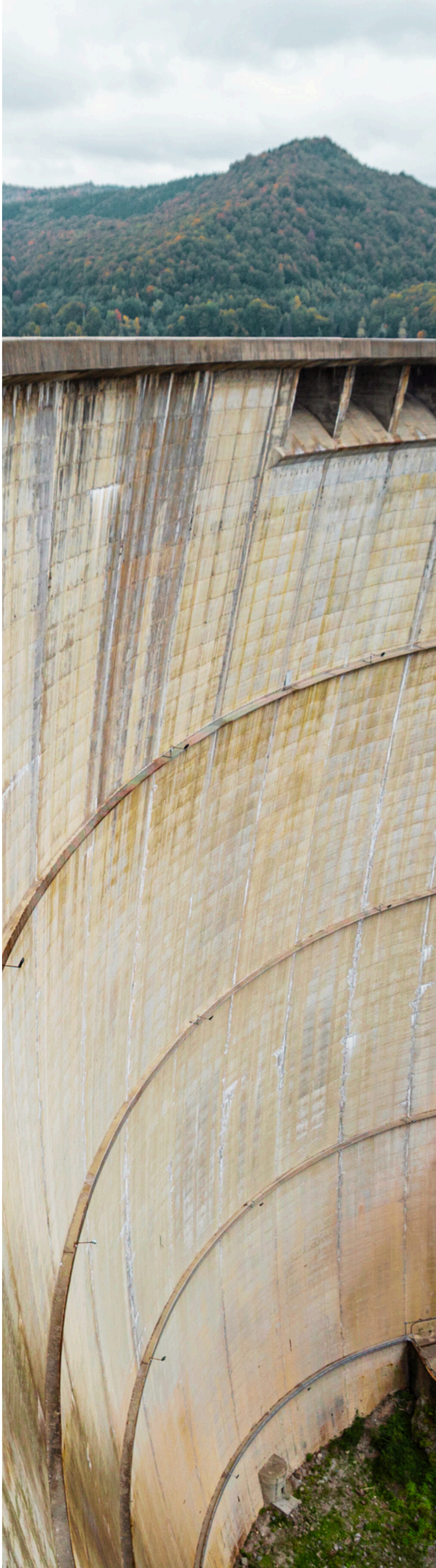

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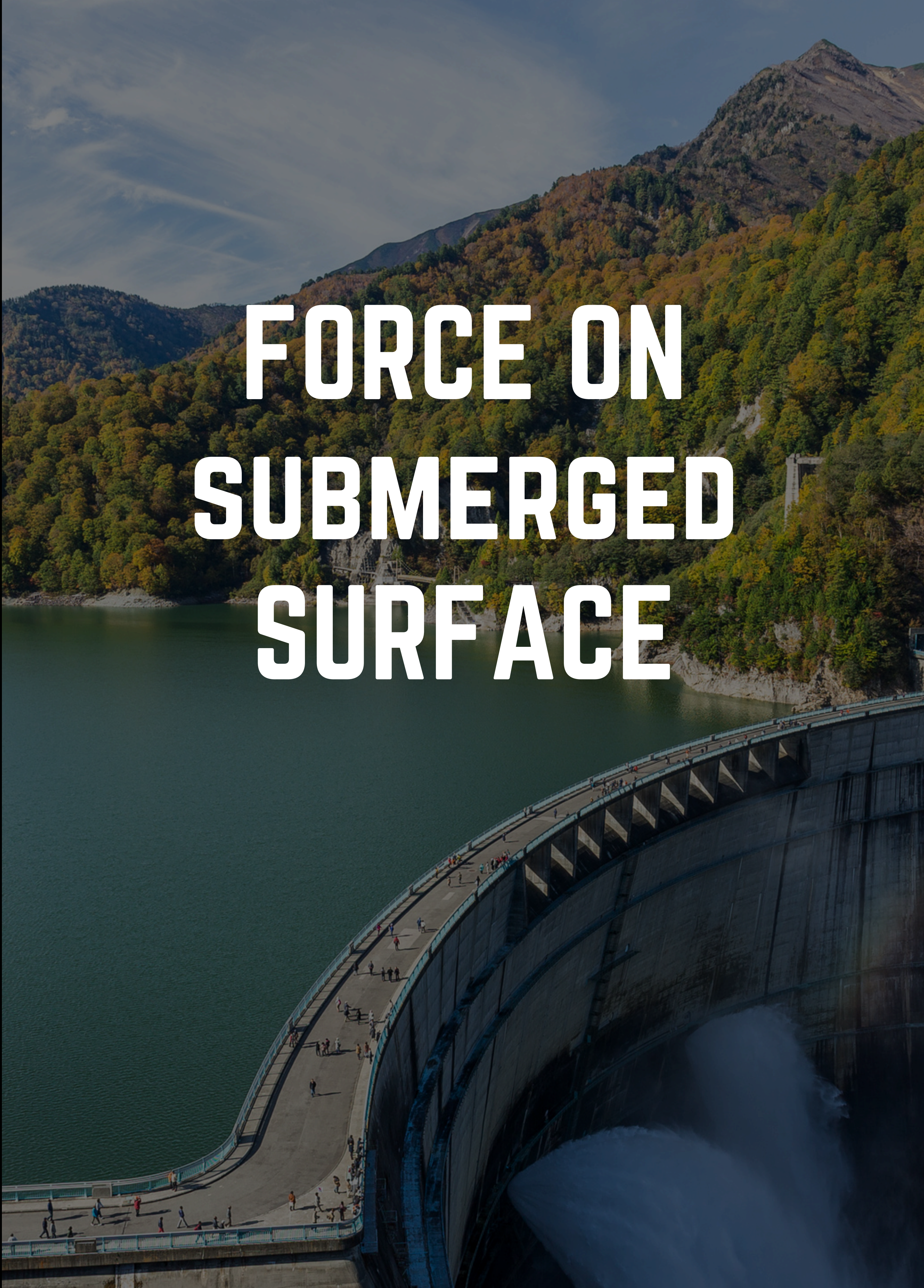


FORCE ON SUBMERGED SURFACE

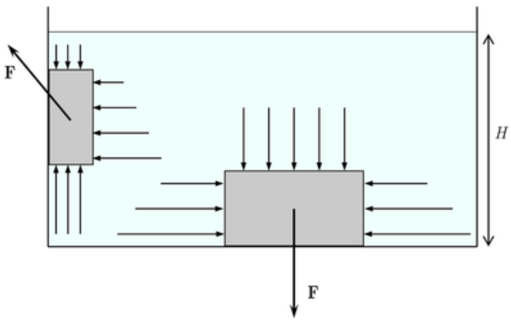
CHAPTER 1

Forces on Submerged Surface

Forces on submerged surfaces are the result of the pressure distribution on the surface, caused by the fluid in which it is submerged. These forces can be used to determine the stability and strength of various structures and components. The fluid can be a liquid or a gas, and the submerged surface can be of any shape or size.

The most common force on submerged surfaces is the hydrostatic force, which is the force exerted on the surface due to the pressure distribution of the fluid. This force is always perpendicular to the surface and is dependent on the density of the fluid, the depth of the surface, and the surface area. The hydrostatic force is used in various applications, such as calculating the buoyancy force on a submerged object or the force on a dam due to the water pressure.

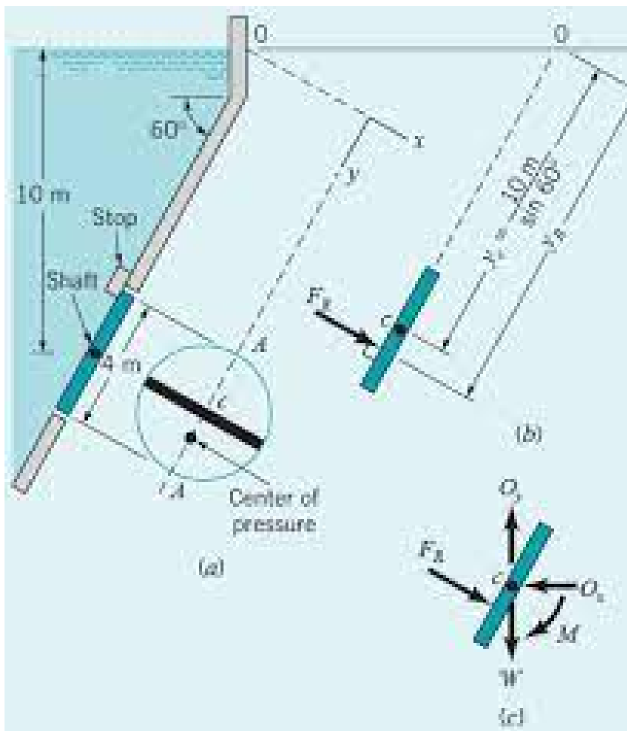
Another force on submerged surfaces is the hydrodynamic force, which is the force exerted on the surface due to the motion of the fluid. This force is dependent on the fluid velocity, the viscosity of the fluid, and the shape and size of the surface. The hydrodynamic force is used in various applications, such as determining the drag force on a ship or the lift force on an airplane wing.



What is Meant by Forces on Submerged Surfaces?

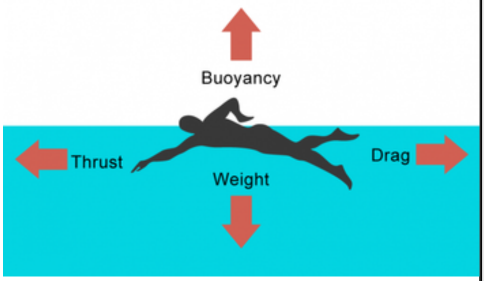
The forces on submerged surfaces can also be affected by other factors, such as the orientation and angle of the surface, the surface roughness, and the presence of other objects or obstructions in the fluid.

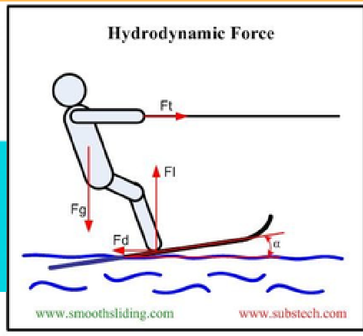
Therefore, the calculation and analysis of these forces require a detailed understanding of fluid mechanics and the physical properties of the surface and the fluid. By understanding the forces on submerged surfaces, engineers and designers can optimize the design and performance of various structures and devices, and ensure their safety and stability in different operating conditions.



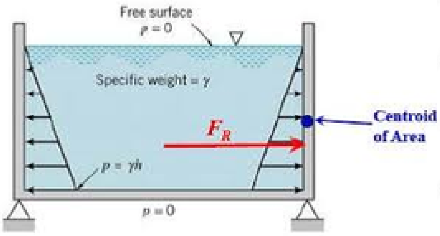
Types of Forces on Submerged Surfaces

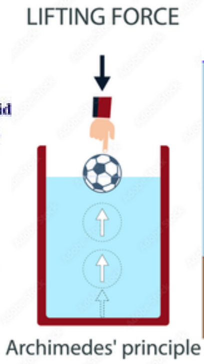
There are several types of forces on submerged surfaces, including hydrostatic forces, hydrodynamic forces, and other forces caused by fluid flow or external factors. Here are some of the main types of forces on submerged surfaces:

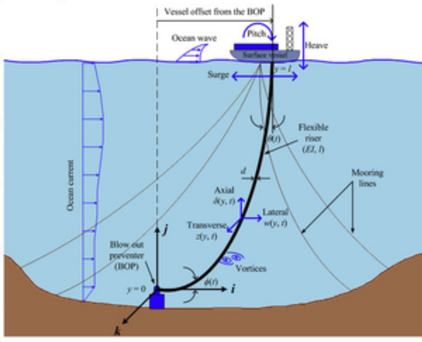




- Hydrostatic Forces
- Hydrodynamic Forces
- Lift Forces
- Drag Forces
- Vortex-induced Forces

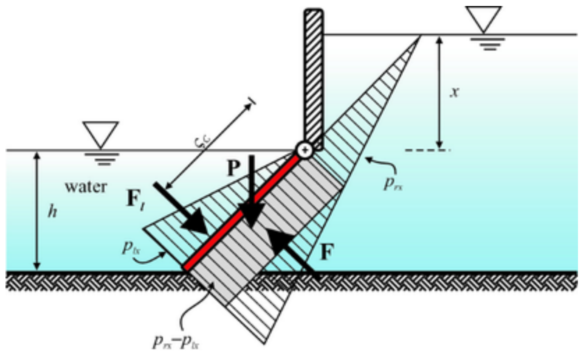




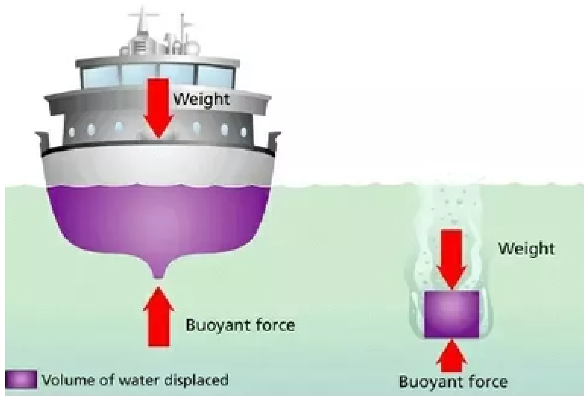


What is HYDROSTATIC FORCE?

Hydrostatic forces are the forces exerted on a submerged surface due to the pressure distribution of the fluid. These forces are always perpendicular to the surface, and their magnitude is dependent on the depth of the surface, the surface area, and the density of the fluid.



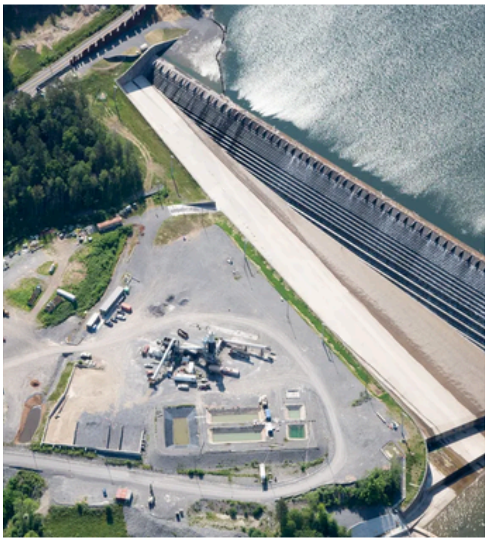
Hydrostatic force is commonly used in various applications such as determining the buoyancy force on a submerged object or the force on a dam due to the water pressure.



The calculation of hydrostatic forces involves using the basic principles of fluid mechanics and the physical properties of the fluid and the surface. For example, in a fluid with uniform density and pressure distribution, the hydrostatic force on a flat surface is proportional to the depth of the surface and the surface area.

Applications of Forces on submerged Surfaces

Forces on submerged surfaces have a wide range of applications in various fields, such as civil engineering, mechanical engineering, marine engineering, and aerospace engineering. Here are some examples:



Dams & levees

Hydrostatic forces play a critical role in the design and analysis of dams and levees. The hydrostatic force acting on the structure must be calculated accurately to ensure the stability and safety of the structure.

Ships & submarines

Hydrodynamic forces, including lift, drag, and vortex-induced forces, are important factors in the design and performance of ships and submarines. The shape and size of the hull, the propulsion system, and the control systems must be optimized to minimize the drag and maximize the lift.

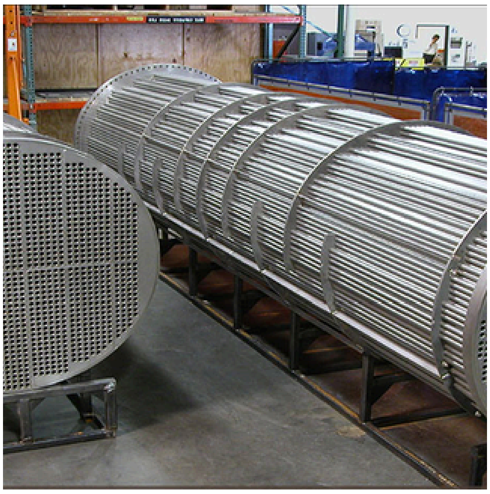
Wind turbines

Hydrodynamic forces are also important in the design of wind turbines. The lift and drag forces on the turbine blades must be optimized to maximize the energy output and minimize the structural stress.

Applications of Forces on submerged Surfaces

Aircraft

Lift and drag forces are critical in the design and operation of aircraft. The shape and size of the wing, the angle of attack, and the airspeed must be optimized to maximize the lift and minimize the drag.



Heat exchangers

Hydrodynamic forces can affect the performance of heat exchangers, such as tube bundles and shell-and-tube heat exchangers. The flow rate, velocity, and pressure drop must be optimized to maximize the heat transfer and minimize the pressure drop.

Bridges and towers

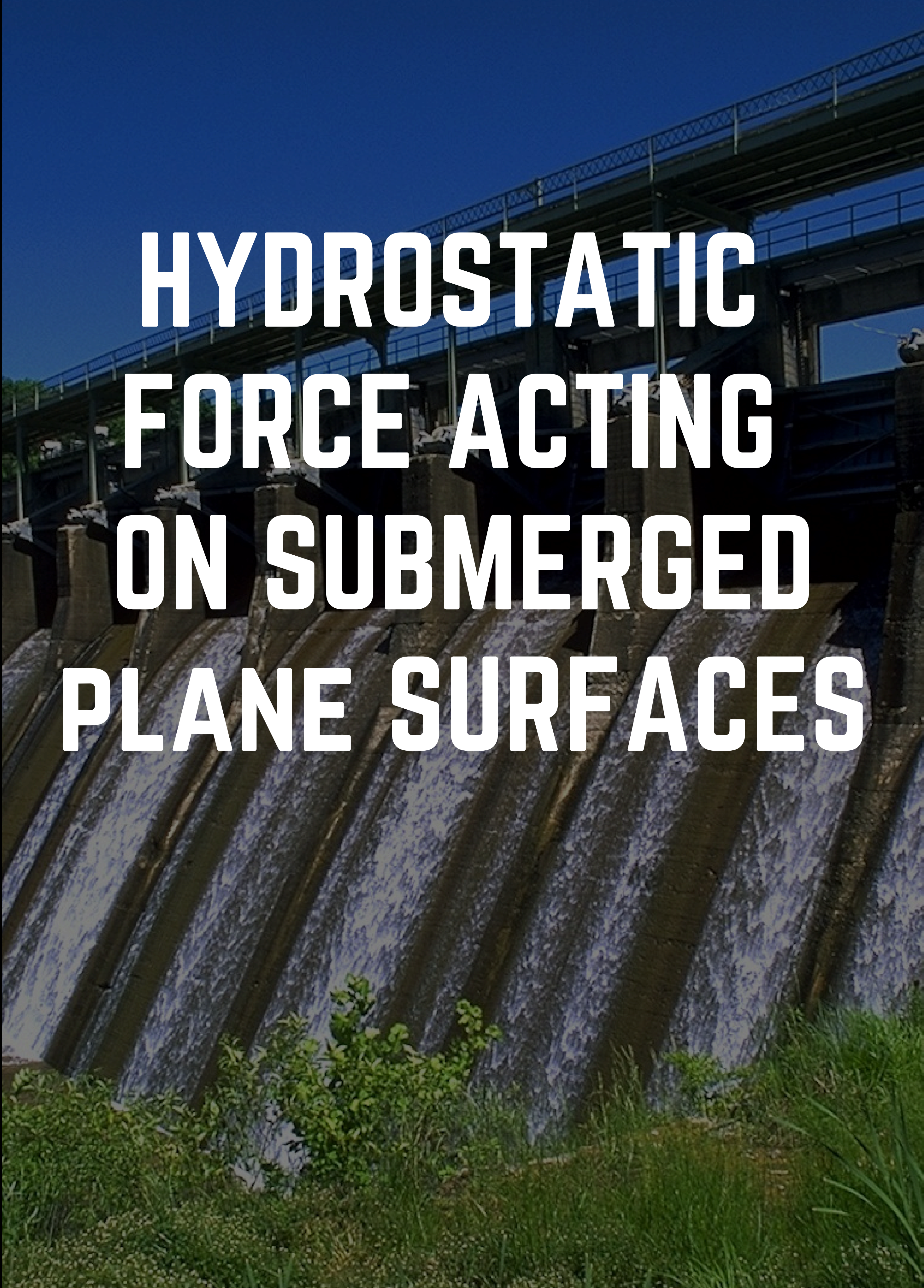
Vortex-induced forces can cause vibrations and fatigue in cables, towers, and other structural components of bridges and towers. The geometry and orientation of the structure must be optimized to minimize the formation of vortices and the resulting forces.

Summary

In each of these applications, understanding and controlling the forces on submerged surfaces is critical to ensuring the safety, efficiency, and performance of the structure or device. Engineers and scientists must use advanced knowledge of fluid mechanics and computational methods to accurately calculate and predict these forces, and to optimize the design and operation of the structure or device.

IT'S TIME FOR

HYDROSTATIC FORCE ACTING ON SUBMERGED PLANE SURFACES

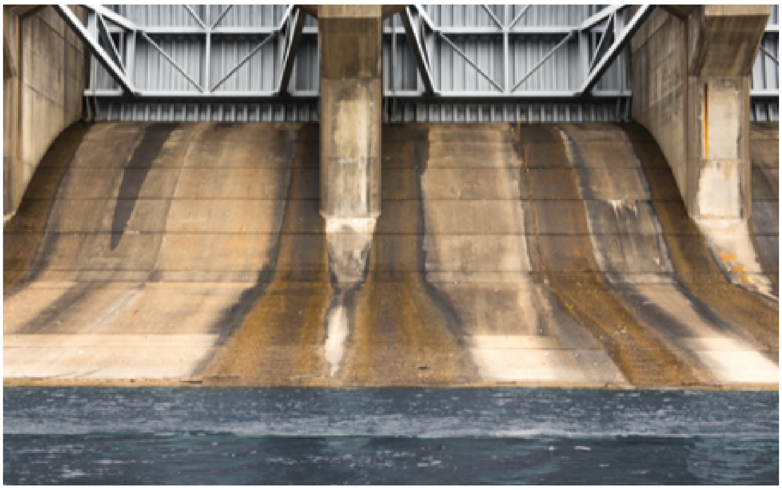


CHAPTER 2

Dam Gates

The purpose of dam is to control water movement, but a big aspect contributing to their differences is what type of dam gates they're built with.

Dams serve several critical purposes for modern society. This includes access to drinking water, irrigation, flood control, hydropower generation, and even recreation.



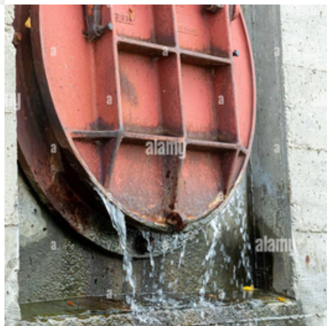
TYPES OF DAM GATES

Radial Gate

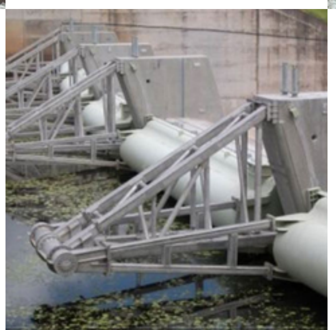
Vertical Lift Gates

Stop Dam Gate Shutter

Round Circular Red Sluice Gate



High-Pressure Slide Gates



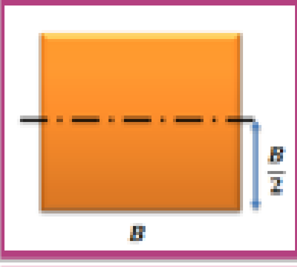
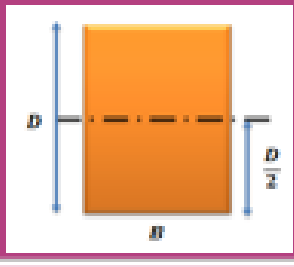
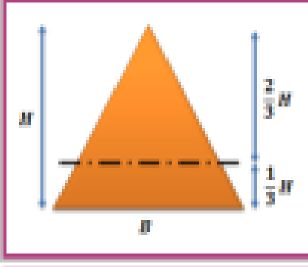
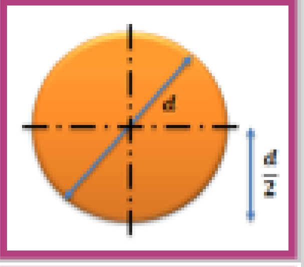
Crest Gate

Drum Gates

CLICK HERE

Miter Gates

Geometric Properties Of Plane Surface

Shape	square	rectangle	triangle	circle
				
Area	$A = B^2$	$A = BD$	$A = \frac{1}{2} BH$	$A = \frac{\pi d^2}{4}$
I_c	$I_c = \frac{B^4}{12}$	$I_c = \frac{BD^3}{12}$	$I_c = \frac{BH^3}{36}$	$I_c = \frac{\pi d^4}{64}$

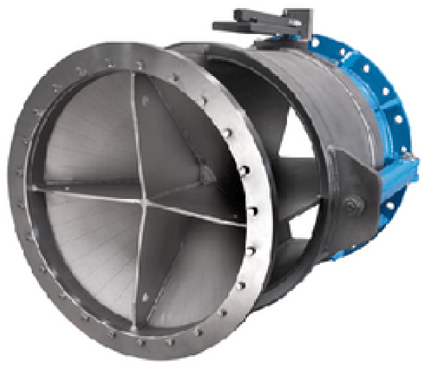
SEVERAL SHAPE OF DAM GATES & VALVES

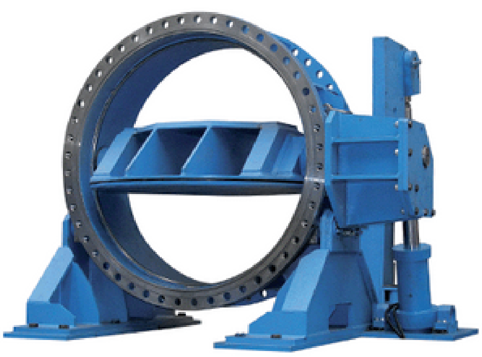
There are several types of dam gates and valves. The dam gates and valves have different types of shapes such as square, rectangle, triangle, circle and curved surface.

CLICK HERE

1 - CIRCULAR SHAPE

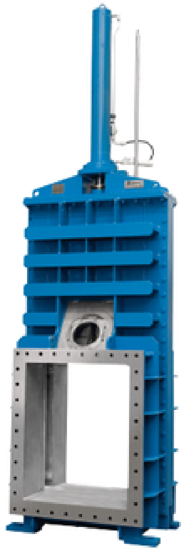
Free discharge energy dissipation fixed cone valve for regulation and closing of bottom and intermediate outlets in dams and reservoirs



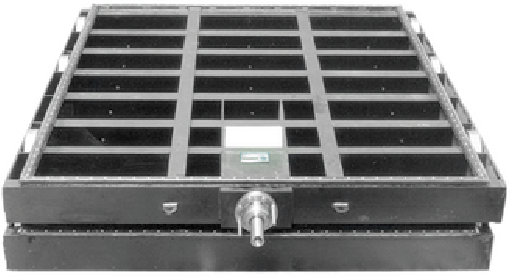


Round port butterfly widely used for flow control in water intakes and outflow/discharge applications (turbine protection and maintenance closing of pipes and penstocks in dams and reservoirs).

2 - SQUARE & RECTANGLE SHAPE

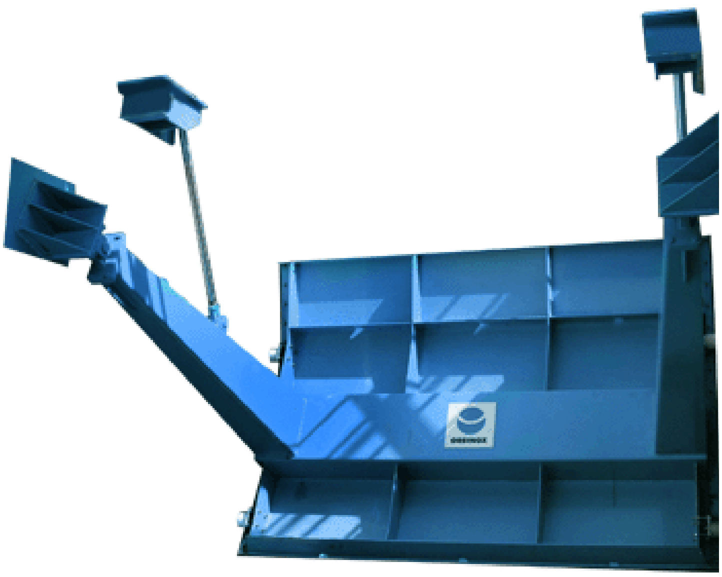


Square and rectangular section flush bottom bonneted gate designed according to Bureau of Reclamation standards for bottom outlets in dams and reservoirs



Rectangular or square section roller gate with wheels for closing large size openings and penstocks with high water heads

3 - CURVED SHAPE

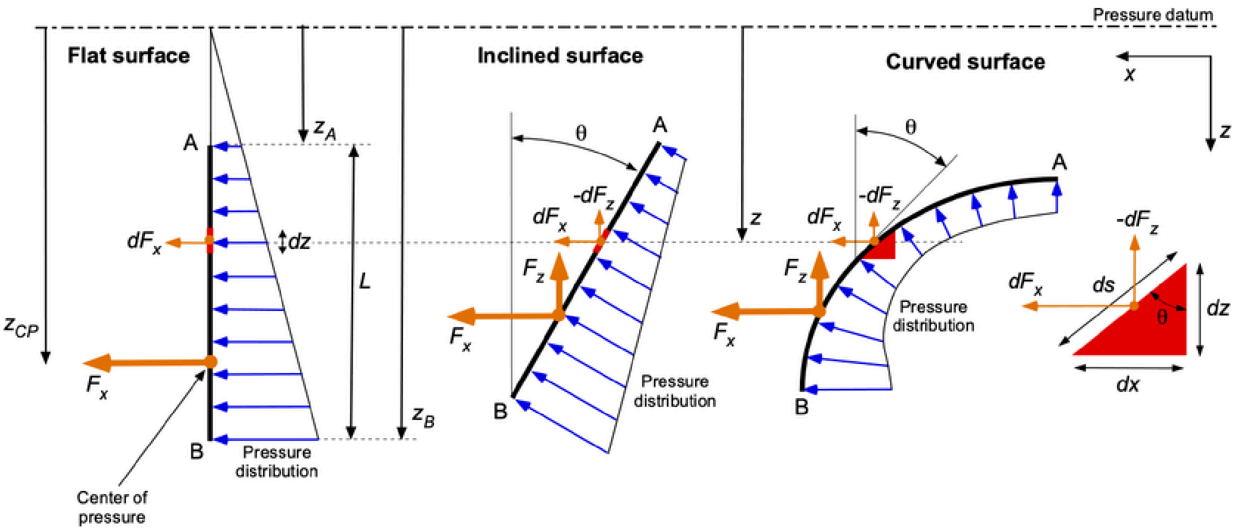


Pivoting radial or taintor gate for water level control in channels and spillways and for regulation and discharge of bottom outlets in dams and reservoirs

HYDROSTATIC FORCE ACTING ON SUBMERGED PLANE SURFACES

A plate, such as a gate valve in a dam, the wall of a liquid storage tank, or the hull of a ship at test, is subjected to fluid pressure distributed over its surface when exposed to a liquid.

On a plane surface, the hydrostatic forces form a system of parallel forces, and we often need to determine the magnitude of the force and its point of application, which is called the center of pressure. When analyzing hydrostatic forces on submerged surfaces, the atmospheric pressure can be subtracted for simplicity when it acts on both sides of the structure.



CENTROID AND CENTRE OF PRESSURE

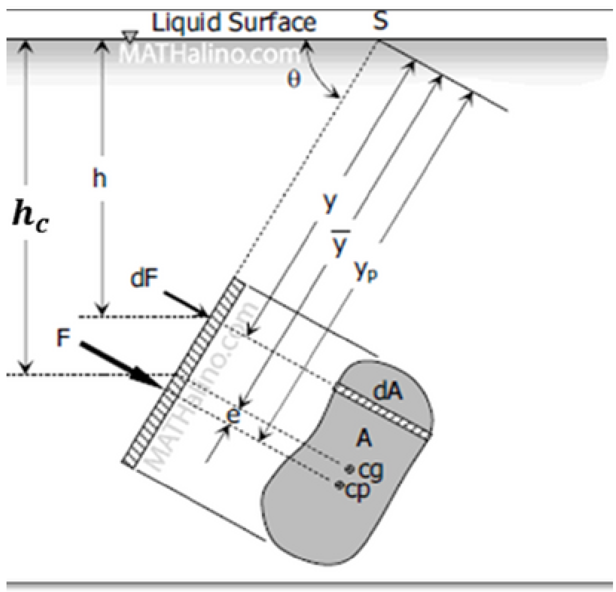
A centroid describes the point in a plane surface located where the sum of distances to the edges of the surface divided by the count of distances equals the average of the distances. A center of pressure describes the point at which a force equal to applied forces exactly offsets those applied.

1 - CENTROID, (CG)

Centroid mean centre of the point where his body weight acts.

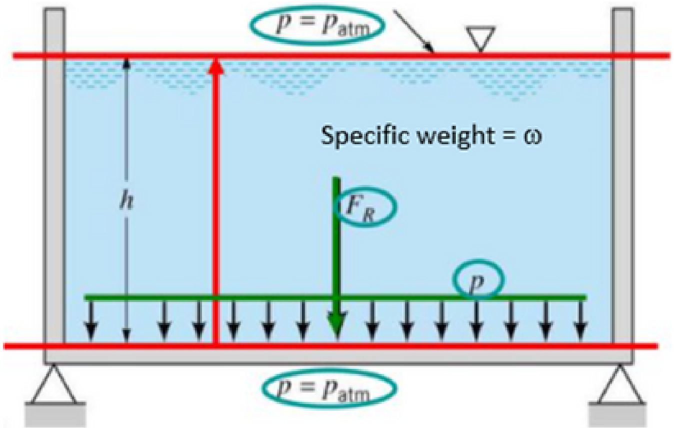
2 - CENTRE OF PRESSURE, (CP)

Is defined as the point of application of the total pressure on the surface.

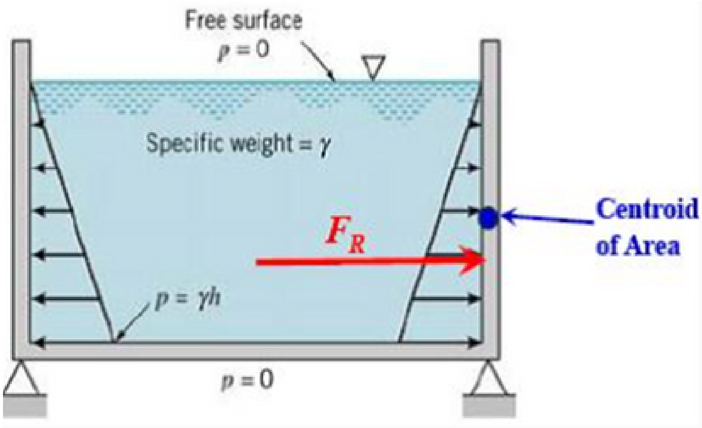


HYDROSTATIC FORCE ACTING ON SUBMERGED PLANE SURFACES

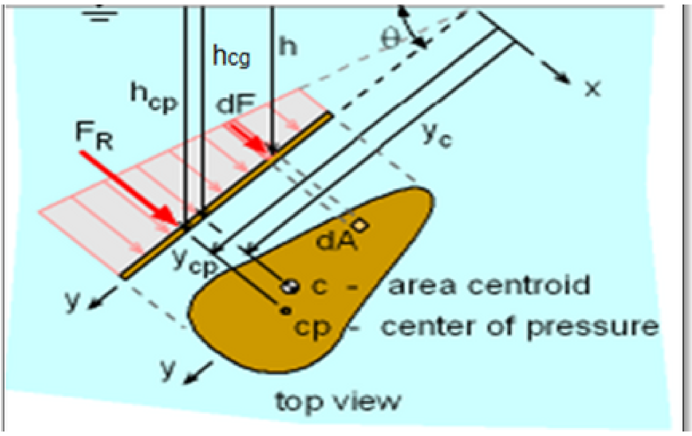
The position of the submerged plane surface may be;



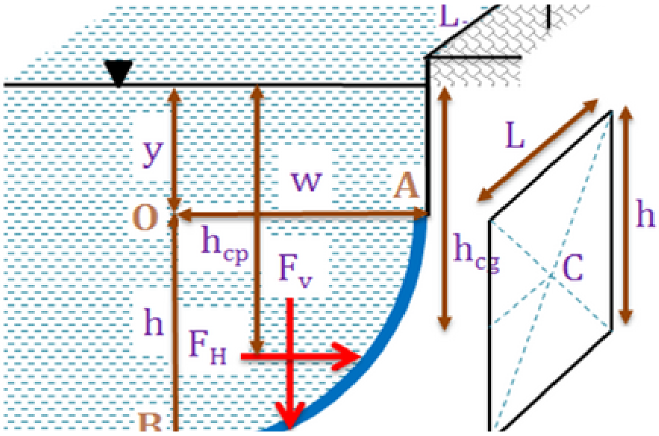
1.0 HORIZONTAL SURFACE



2.0 VERTICAL SURFACE



3.0 INCLINED SURFACE



4.0 CURVED SURFACE

1.0 Horizontal Surface

For horizontal surface, the equations for inclined surface can be used where <u>θ = 0.</u>

For example, the bottom of a tank.

Resultant Force, F_R

$$F_R = \rho g h_{cg} A$$

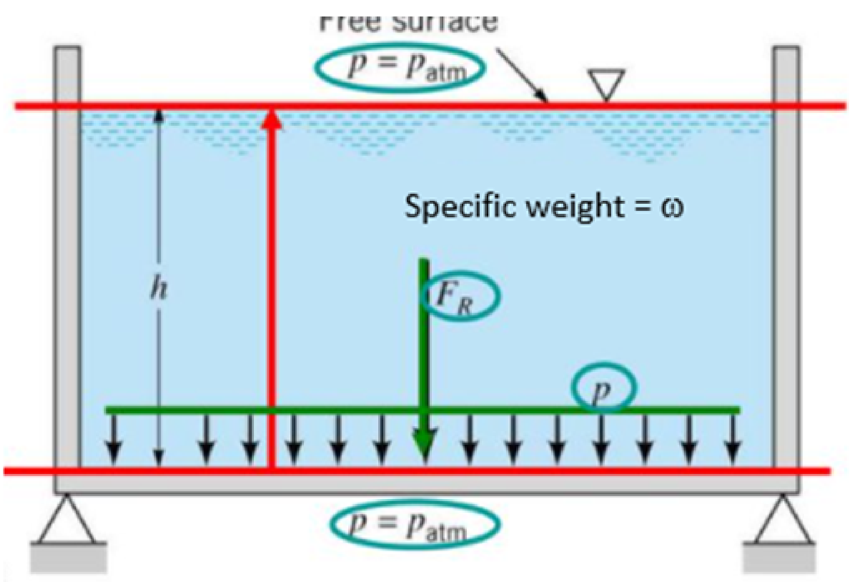
where;

ρ = the density of the liquid (kg/m^3)

g = acceleration due to gravity (kg.m/s^2)

A = area of the submerged surface(m^2)

hcg = height from the fluid surface to the center of gravity of the submerged plane surface (m)



2.0 VERTICAL SURFACE

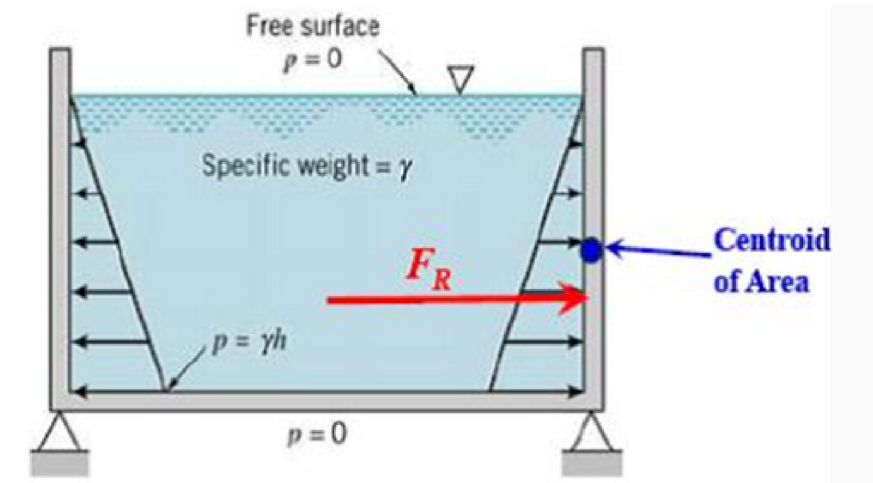
For vertical surface, the equations for inclined surface can be used where θ = 90.

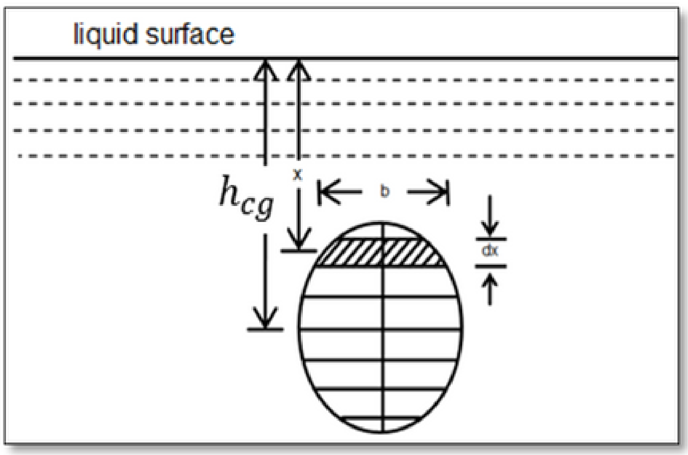
Resultant Force, F_R

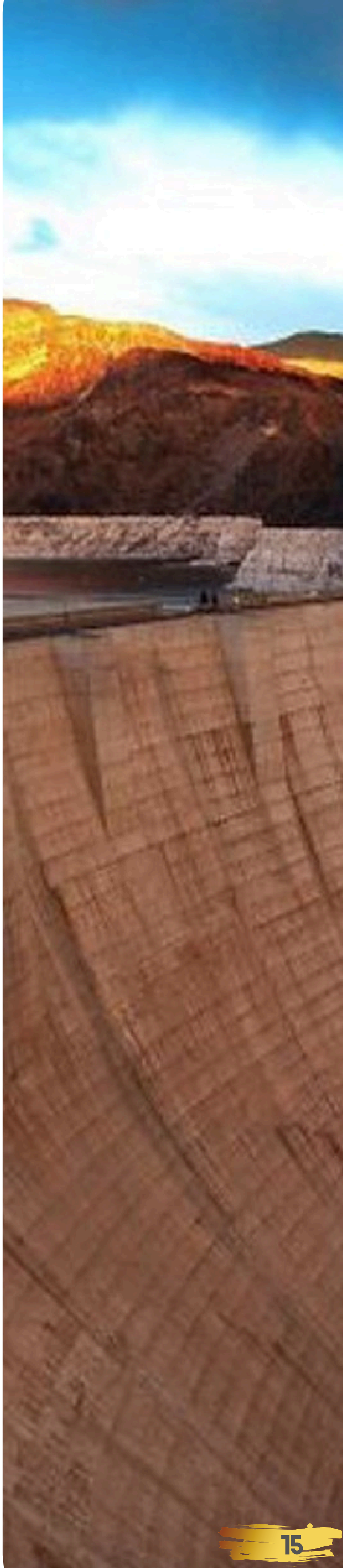
$$F_R = \rho g h_{cg} A$$

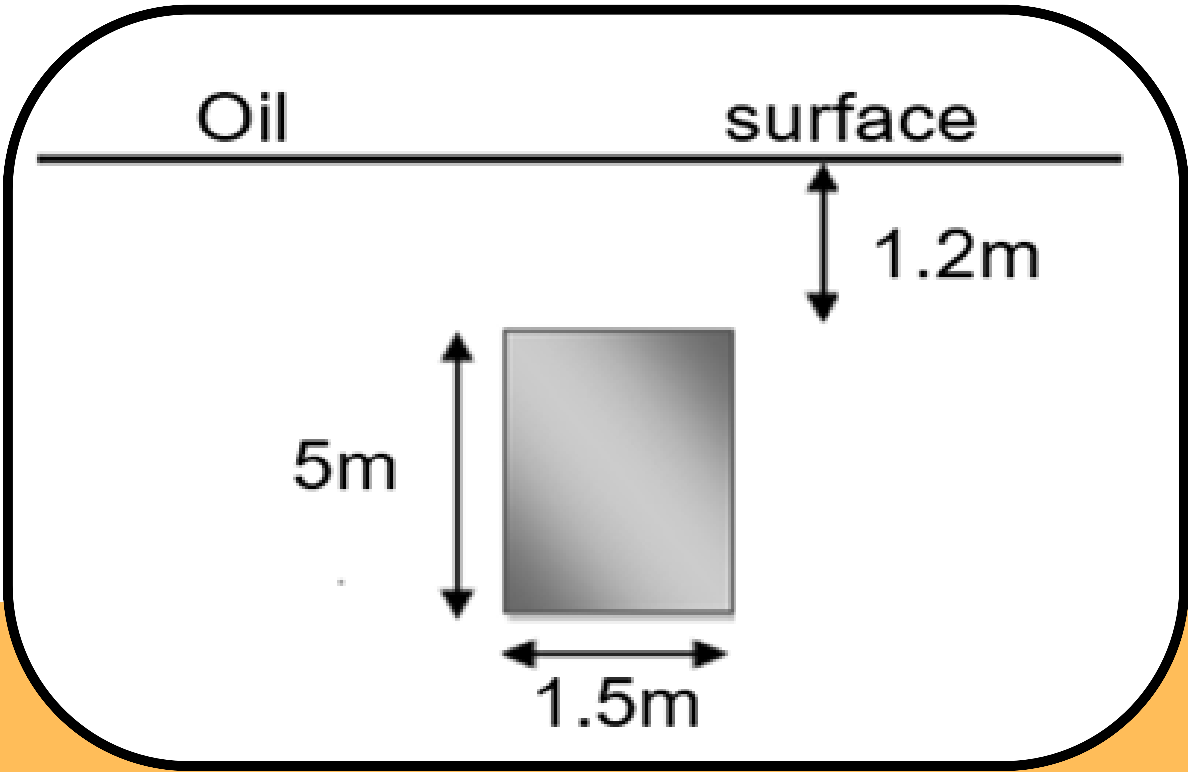
Height of centre of pressure

$$h_{cp} = \frac{I_c \sin^2\theta}{A\, h_{cg}} + h_{cg}$$









EXAMPLE 2.1

A rectangular gate of 1.5 m base and 5 m depth is immersed vertically in an oil of specific gravity 0.90 as shown in figure. Find the resultant force on the gate.

ANSWER

The keyboard is one of the primary input devices, which helps in entering data and commands in a computer. The layout of the keyboard is almost identical to a traditional typewriter with additional keys that help in performing specific tasks. A normal keyboard usually has a variety of keys, such as alphabetic character keys, function keys, number keys, arrow keys, and control keys.

The keyboard can be connected to a computer using USB (for a wired keyboard) or Bluetooth (for a wireless keyboard). There is no specific rule for defining the number of keys; however, most keyboards come in two sizes - 84 keys or 101/102 keys.

Laptops come with inbuilt, more compact keyboards, which help make the laptop smaller and lighter. Besides, most modern devices (such as smartphones, tablets, and convertible touch screen laptops) come with on-screen virtual keyboards that help to input the data into a computer. Most English language keyboards have a QWERTY layout.

3.0 INCLINED SURFACE

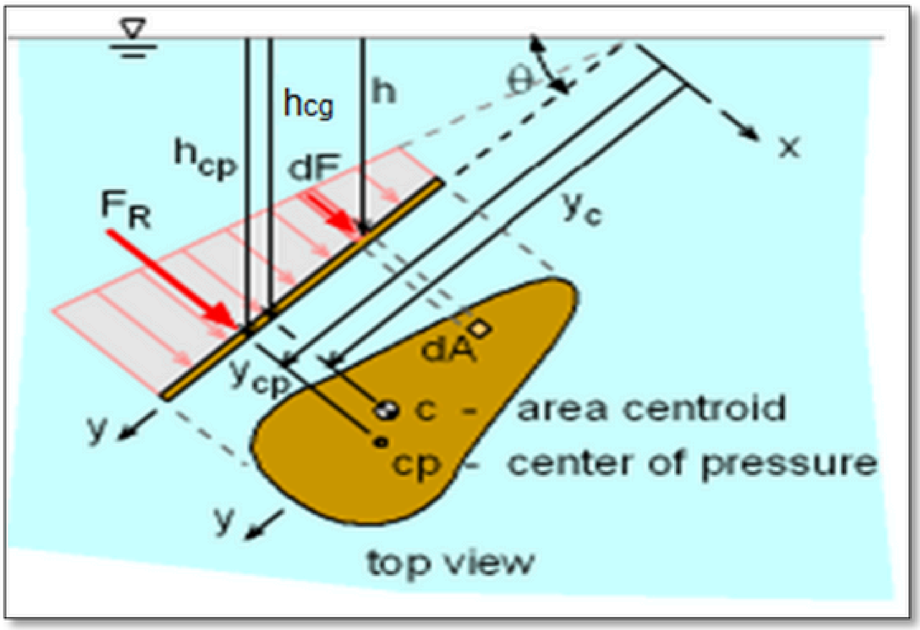
An inclined immersed plane surface, is as shown in the following figure.

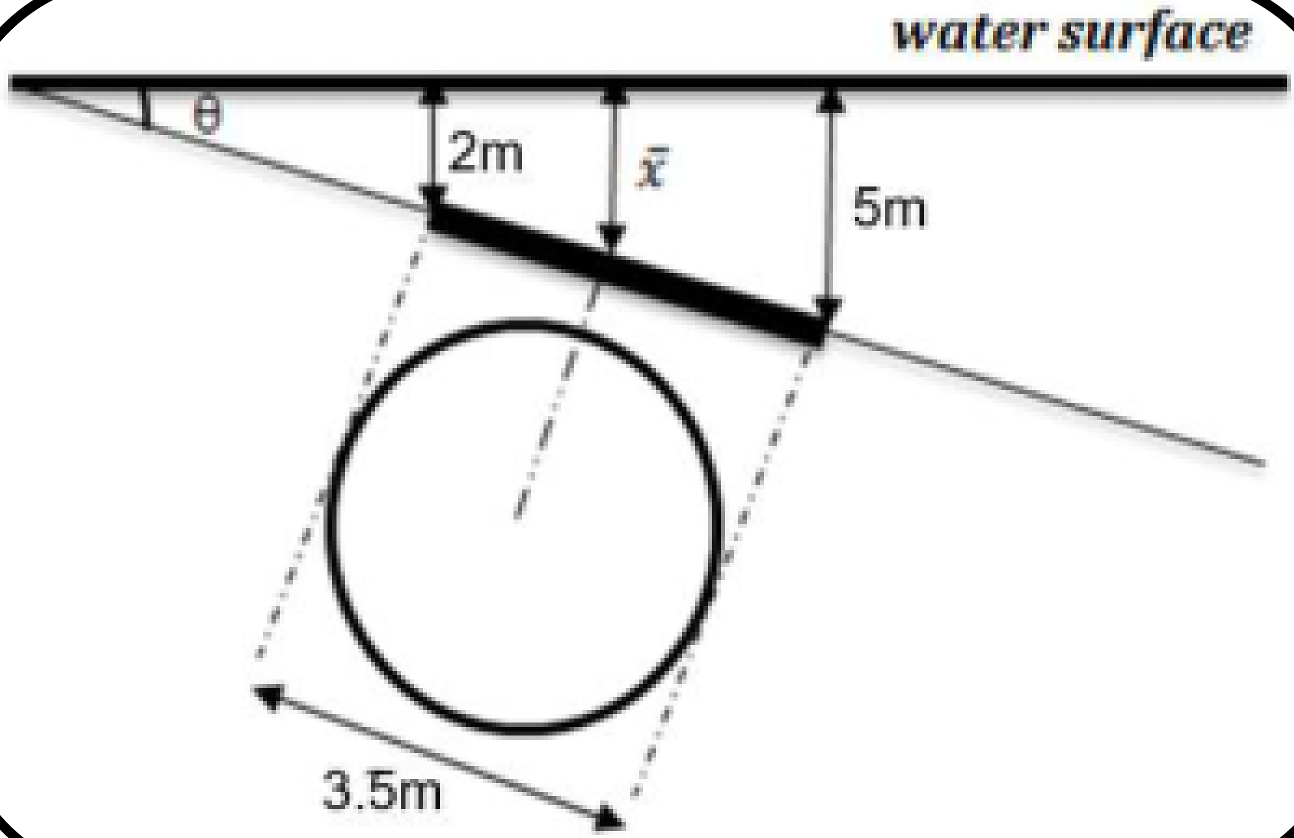
Resultant Force, F_R

$$F_R = \rho g h_{cg} A$$

Height of centre of pressure

$$h_{cp} = \frac{I_c \sin^2\theta}{A\, h_{cg}} + h_{cg}$$





EXAMPLE 3.1

A circular plate of 3.5 m diameter is submerged in water. The greatest and least of the plate are 5 m and 2 m respectively. Find total pressure on the plate and position of the center of pressure.

ANSWER

The keyboard is one of the primary input devices, which helps in entering data and commands in a computer. The layout of the keyboard is almost identical to a traditional typewriter with additional keys that help in performing specific tasks. A normal keyboard usually has a variety of keys, such as alphabetic character keys, function keys, number keys, arrow keys, and control keys.

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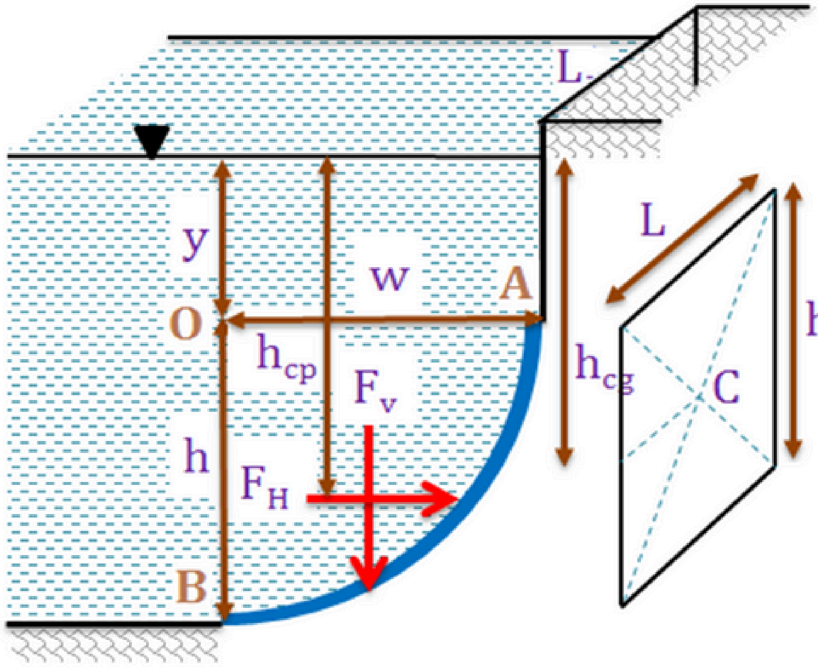
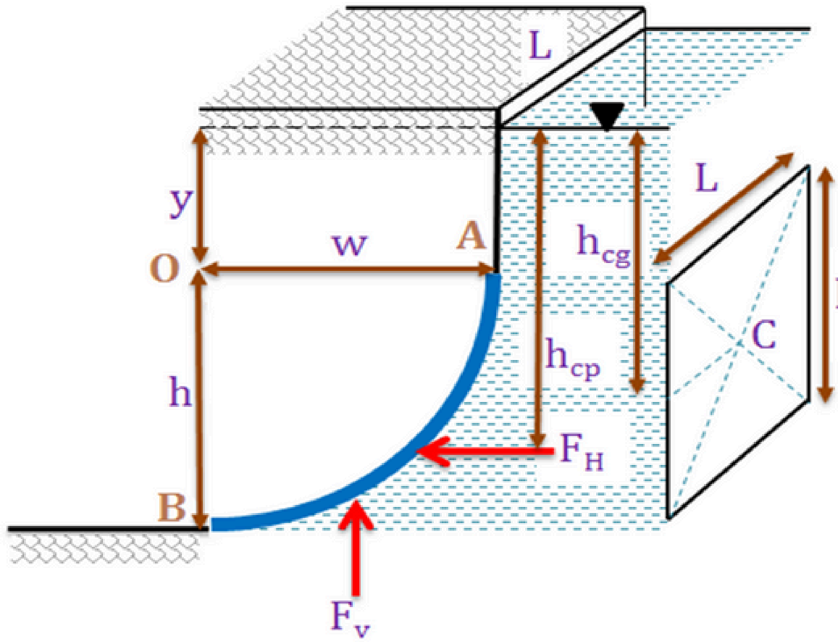
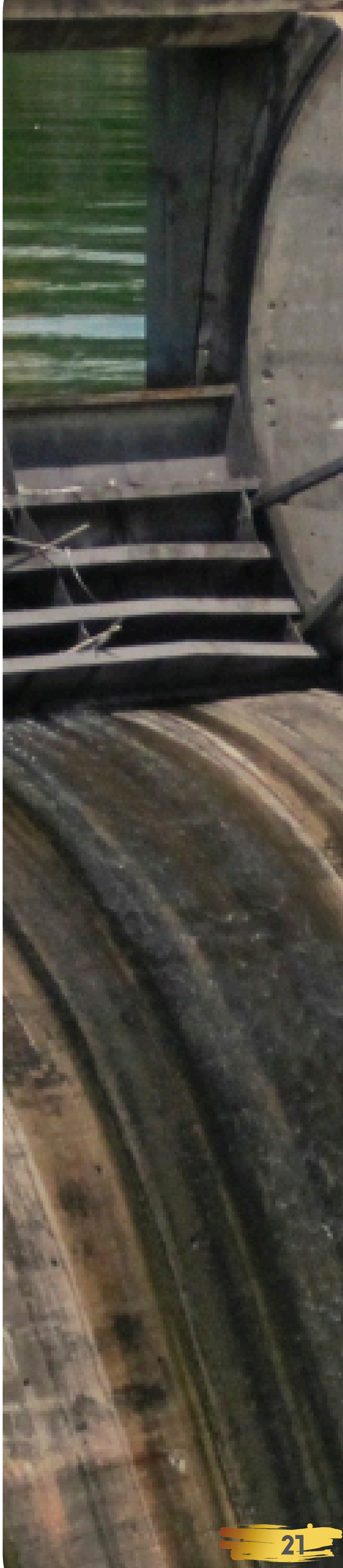
4.0 CURVED SURFACE

Curved surface AB submerged in a fluid are as shown in the following figures.





Two force components: FH and FV



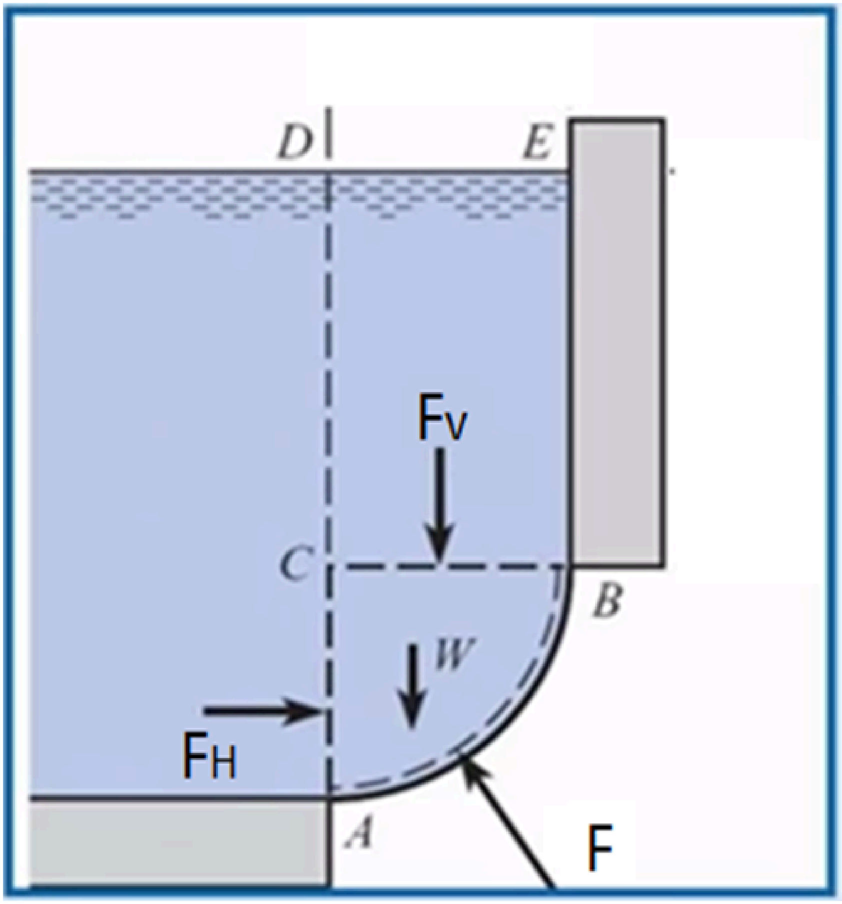
4.0 CURVED SURFACE

FH is the force equivalent to the force acting on the vertical plane surface projected from the curved surface (the rectangular image).

Horizontal Force, F_H

$$F_H = \rho g h_{cg} A$$

$A = heigth\ of\ CA\ x\ width\ of\ gate$
$= h\ x\ L$



4.0 CURVED SURFACE

FV is the force equivalent to the weight of the fluid above the curved surface.

Vertical Force, F_V

$$F_V = \rho g V$$

$$V = V_1 + V_2$$

$$V_1 = w \times h \times L$$

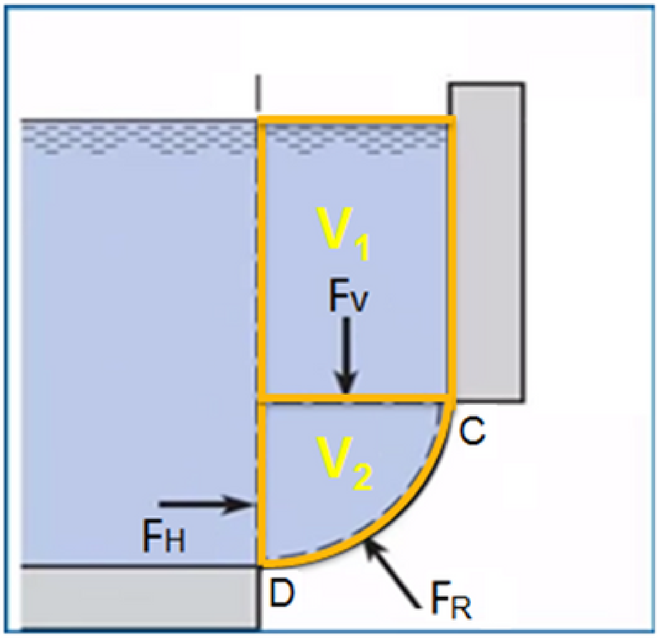
$$V_2 = \frac{\pi (r)^2}{4} \times L$$

where;

ρ = the density of the liquid (kg/m^3)

g = acceleration due to gravity ($kg.m/s^2$)

V = fluid volume above the curved surface up to the fluid surface line (m^3)



4.0 CURVED SURFACE

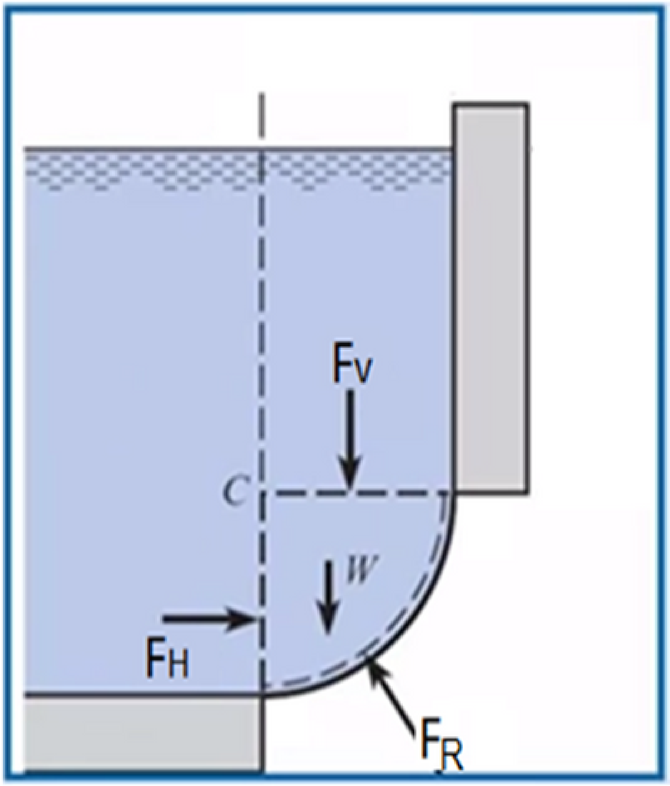
FR of the components FH and FV is;

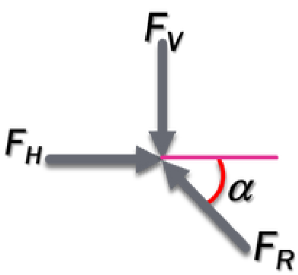
Resultant Force, F_R

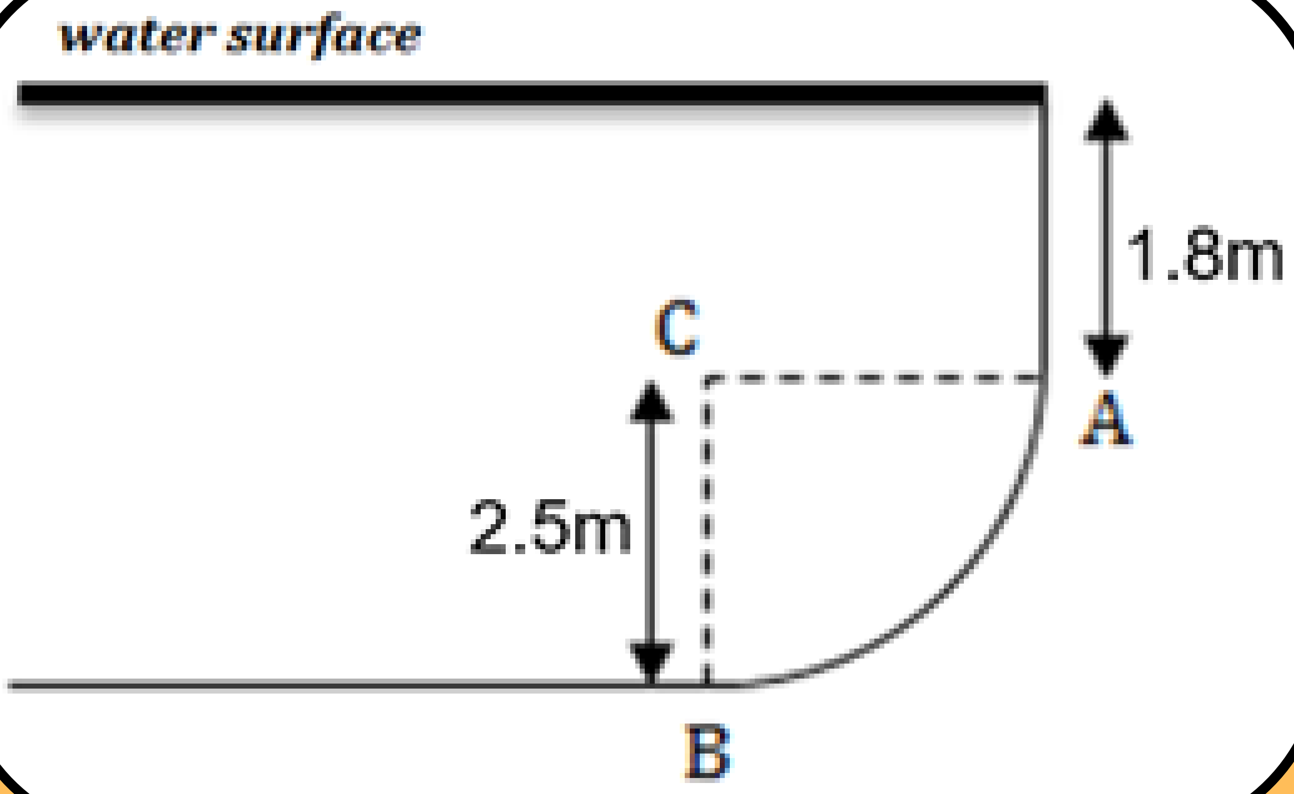
$$F_R = \sqrt{(F_H)^2 + (F_V)^2}$$

F_R act at an angle α from horizontal

$$\tan\alpha = \frac{F_V}{F_H}$$







EXAMPLE 4.1

Determine the total pressure acting on the curved gate of 2.5 m radius and 2 m length of the pool as illustrated in figure. Also determine the angle at which the total pressure will act.

ANSWER

The keyboard is one of the primary input devices, which helps in entering data and commands in a computer. The layout of the keyboard is almost identical to a traditional typewriter with additional keys that help in performing specific tasks. A normal keyboard usually has a variety of keys, such as alphabetic character keys, function keys, number keys, arrow keys, and control keys.

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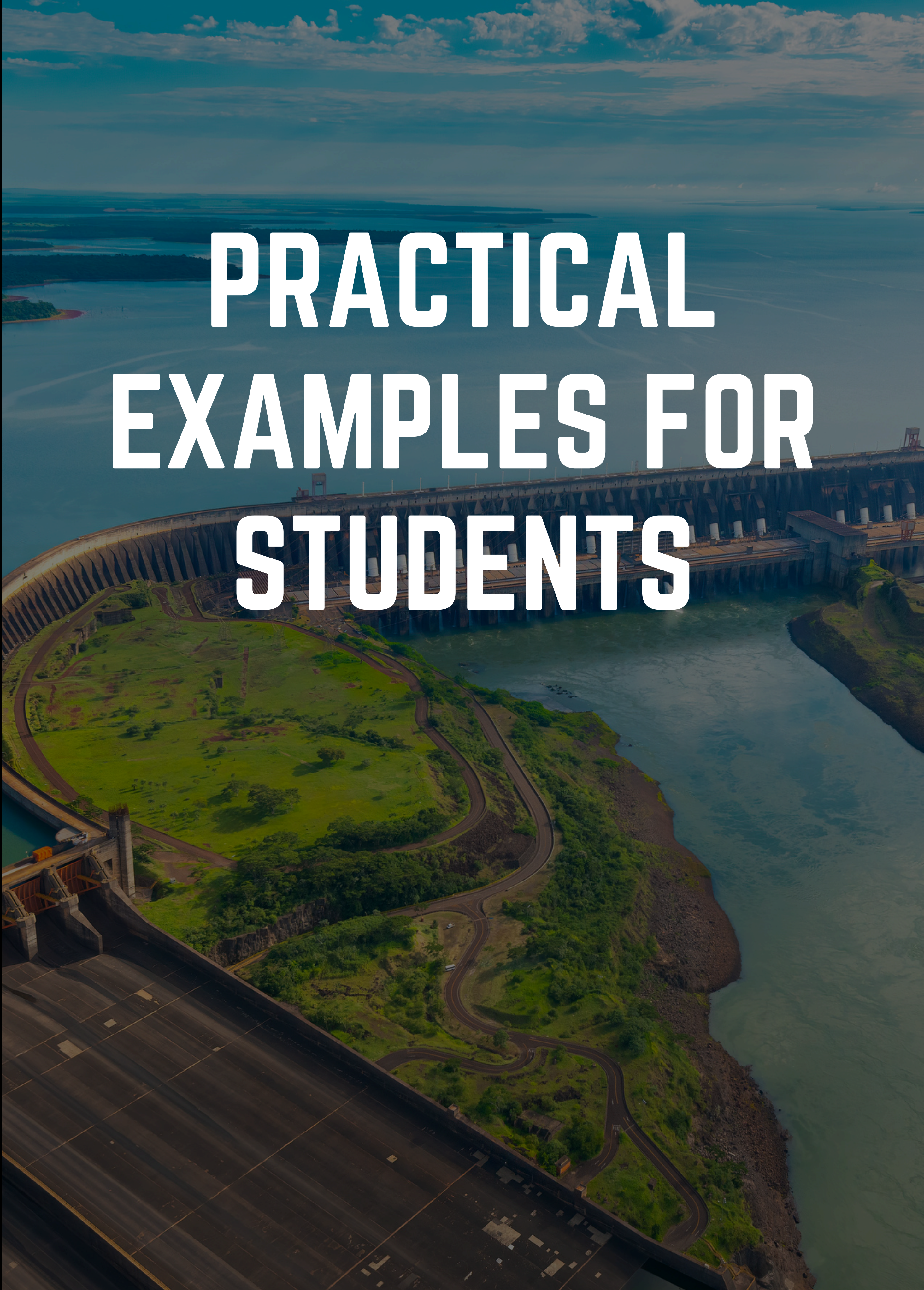
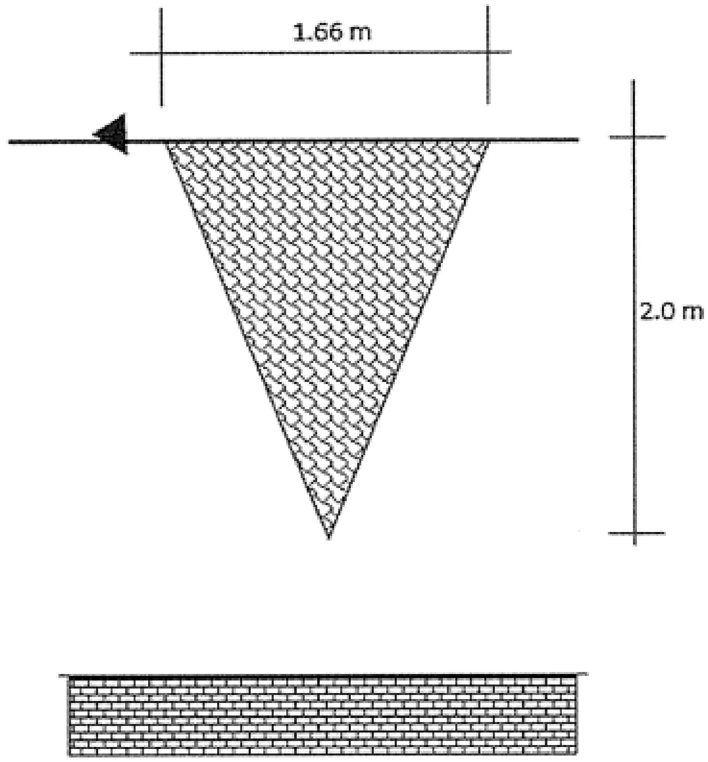


PRACTICAL EXAMPLES FOR STUDENTS

CHAPTER 3

VERTICAL SURFACE



EXAMPLE 1 (SESSION 1 : 2022/2023)

A triangular plate of 1.66 m base and 2.0 m height is immersed vertically in liquid as shown in Figure 1 (b) with specific weight of 10 kN/m^3. Calculate the total hydraulic force on the plate (F) and the depth of centre of pressure (h_p).

Sekeping plat segitiga berukuran 1.66 m pada tapak dan tinggi 2.0 m, tenggelam secara menegak di dalam cecair seperti yang ditunjukkan dalam Rajah 1 (b) dengan berat tentu 10 kN/m^3. Kirakan jumlah daya hidraulik pada plat (F) dan kedalaman pusat tekanan (h_p).

ANSWER

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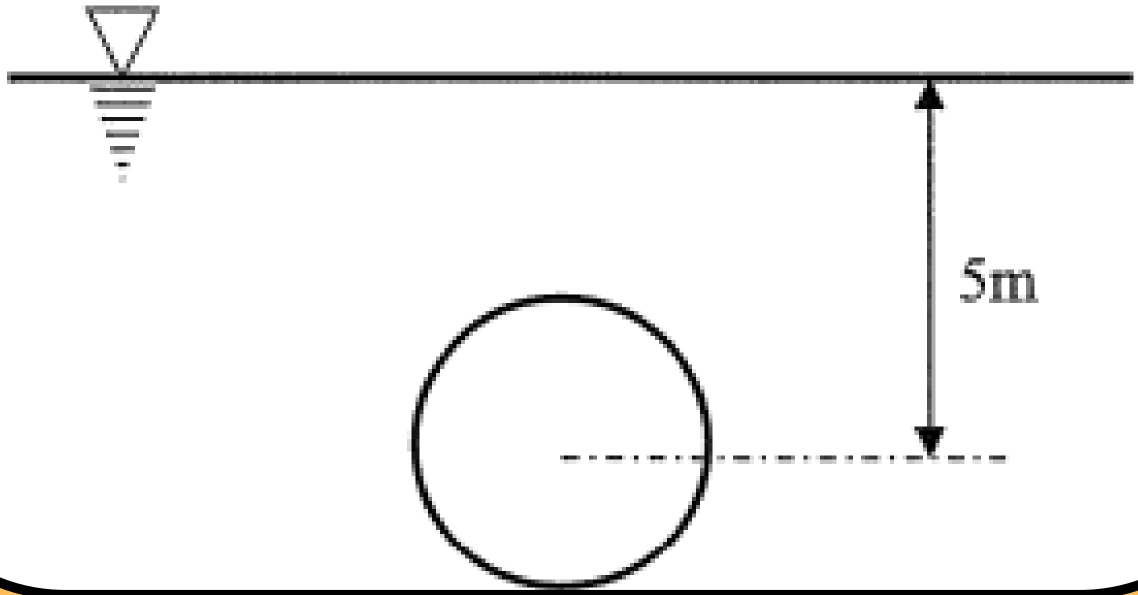
VERTICAL SURFACE



EXAMPLE 2 (Session 1 : 2023/2024)

A plate as shown in Figure A1(b) with 2.0 m diameter submerged vertically into water. Distance from the fluid surface to the centre of gravity is 5.0 m. Identify the total pressure on the plate.

Sekeping plat seperti Rajah A1(b) berdiameter 2.0 m tenggelam secara menegak ke dalam air. Jarak pusat graviti plat adalah 5.0 m dari permukaan air. Kenal pasti jumlah tekanan yang dikenakan ke atas plat.

ANSWER

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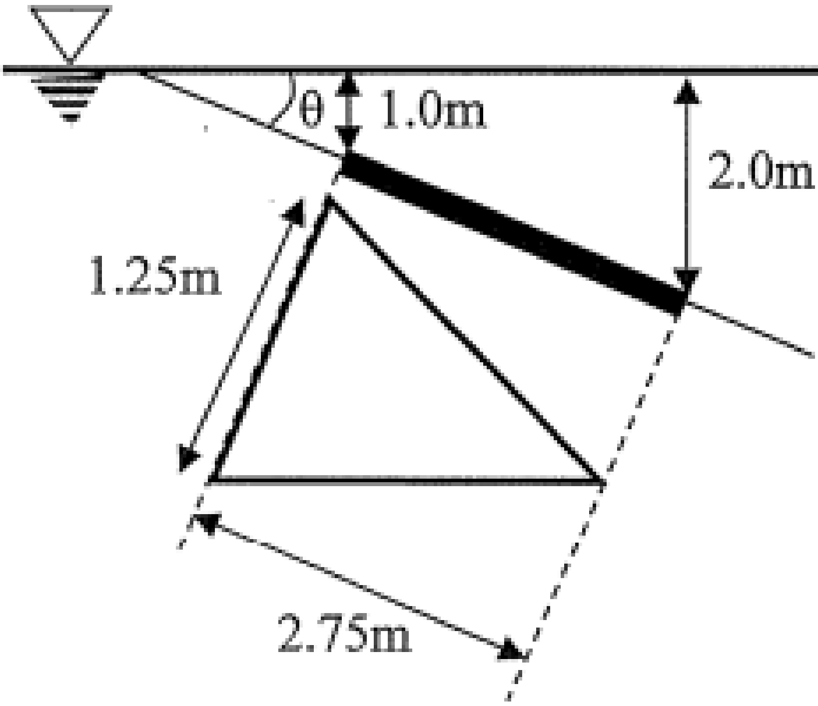
INCLINED SURFACE



EXAMPLE 3 (Session 1 : 2023/2024)

Figure A1(c) shows a triangular plate of 1.25 m base and 2.75 m height was immersed in water. The distance from the upper and edge of the plate to the water surface is 1.0 m and 2.0 m. Determine the hydrostatic force on the plate and position of the centre of pressure.

Rajah A1(c) menunjukkan plat segitiga dengan tapak 1.25 m dan tingginya 2.75 m tenggelam di dalam air. Jarak dari atas dan hujung plat ke permukaan air adalah masing-masing 1.0 m dan 2.0 m. Tentukan daya hidrostatik ke atas plat dan kedudukan pusat tekanan.

ANSWER

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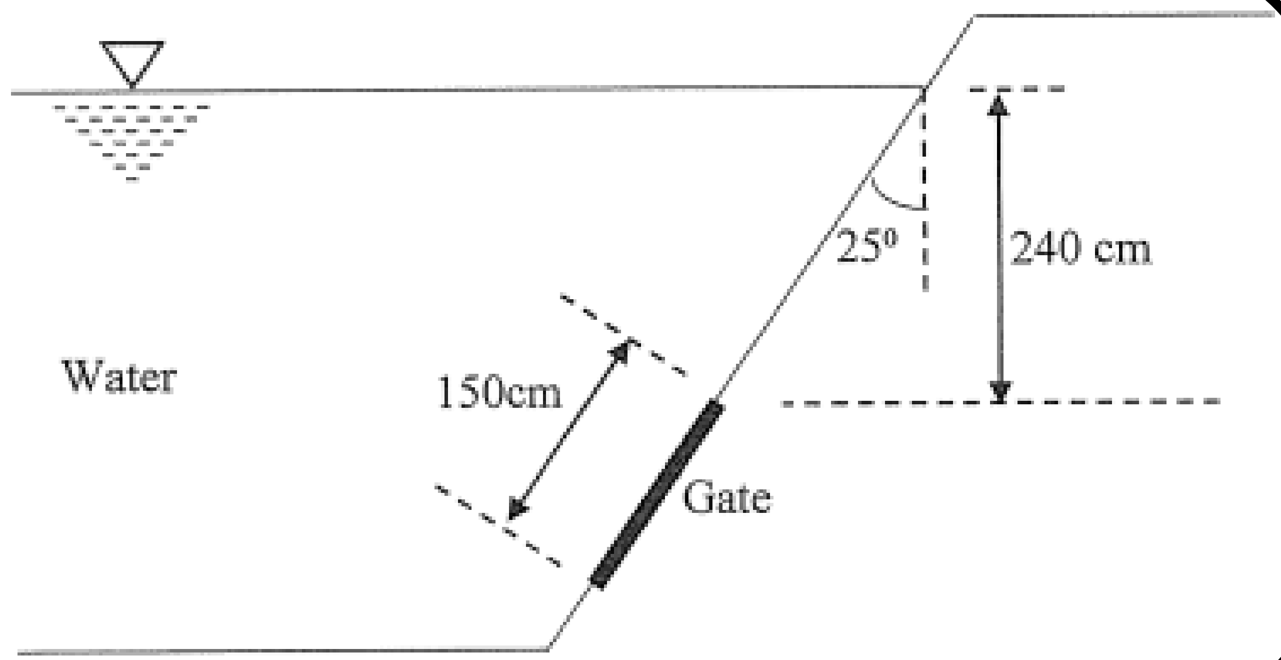
INCLINED SURFACE



EXAMPLE 4 (SESSION 2 : 2021/2022)

An inclined circular water gate with diameter 150cm is immersed as shown in **Figure A3**. The water gate is place 240cm below the water surface. Find out the total hydrostatic force acting on the gate.

Sebuah pintu air bulat berdiameter 150cm tenggelam secara condong seperti ***Rajah A3****. Pintu air terletak di 240cm di bawah permukaan air. Ketahui jumlah daya hidrostatik yang bertindak ke atas pintu.*

ANSWER

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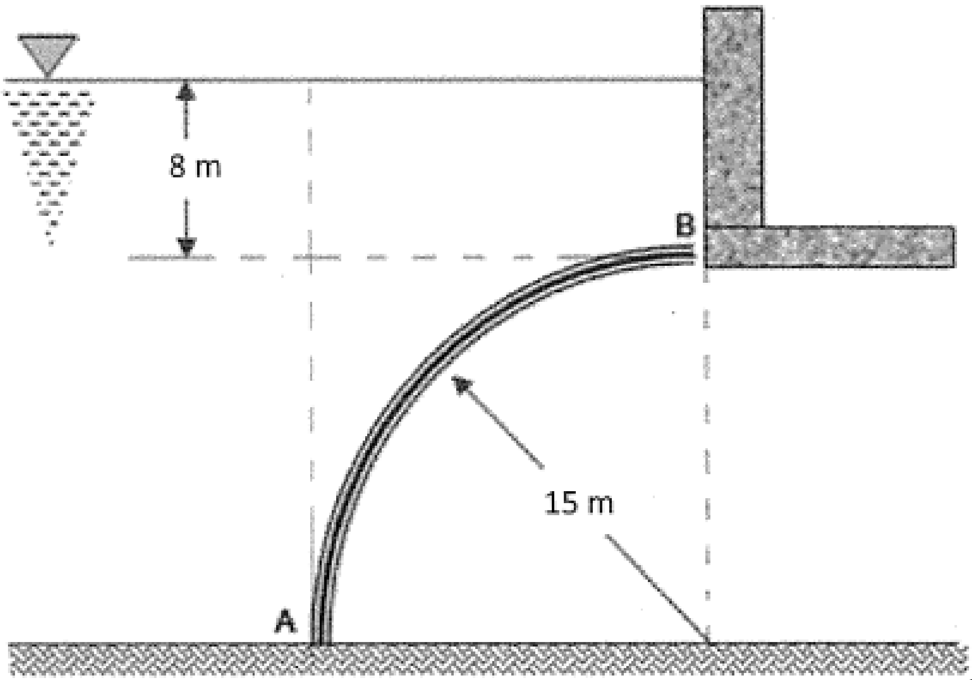
CURVED SURFACE



EXAMPLE 5 (SESSION 1 : 2022/2023)

Calculate the horizontal and vertical force exerted by the fluid on the curved vane AB as shown in Figure 1 (c). Given the fluid density 800 kg/m^3, vane length 6.7 m and radius 15 m.

Kira daya mengufuk dan menegak yang dikenakan oleh bendalir pada ram melengkung AB seperti ditunjukkan dalam Rajah 1(c). Diberi ketumpatan bendalir 800 kg/m^3, panjang ram 6.7 m dan jejari 15 m.

ANSWER

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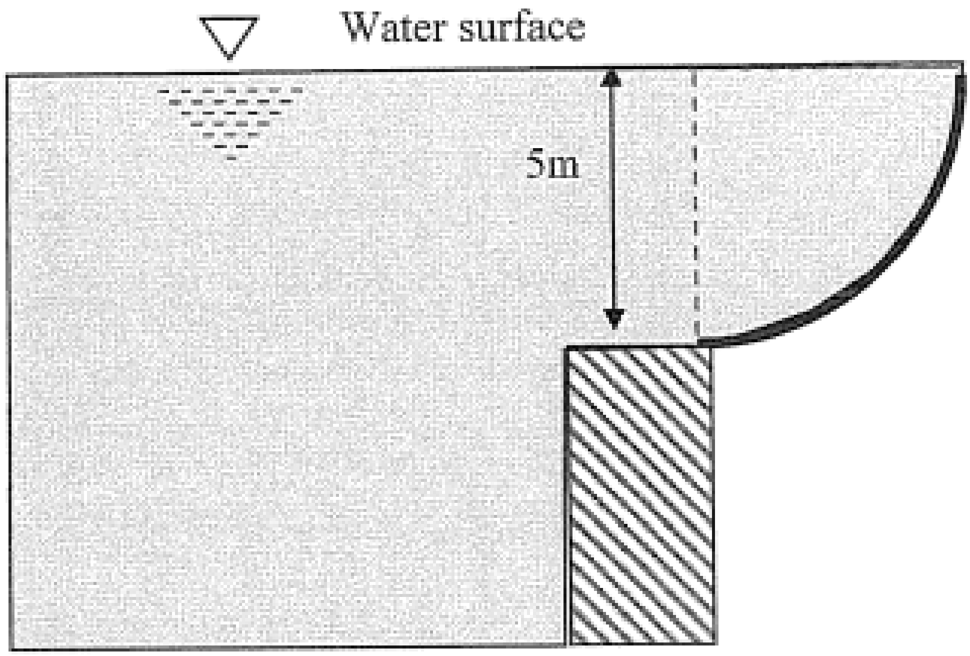
CURVED SURFACE



EXAMPLE 6 (Session 2 : 2021/2022)

Figure A1 shows a gate having a quadrant shape of 5m radius and 10m length. Estimate the horizontal force, F_H exerted to the gate.

Rajah A1 *menunjukkan pintu air berbentuk suku bulatan berjejari 5m dan 10m panjang. Anggarkan daya ufuk,* F_H *yang bertindak pada pintu air tersebut.*

ANSWER

The keyboard is one of the primary input devices, which helps in entering data and commands in a computer. The layout of the keyboard is almost identical to a traditional typewriter with additional keys that help in performing specific tasks. A normal keyboard usually has a variety of keys, such as alphabetic character keys, function keys, number keys, arrow keys, and control keys.

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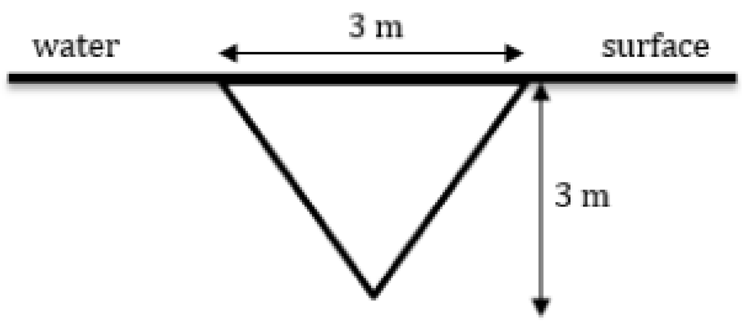
REVIEW QUESTIONS

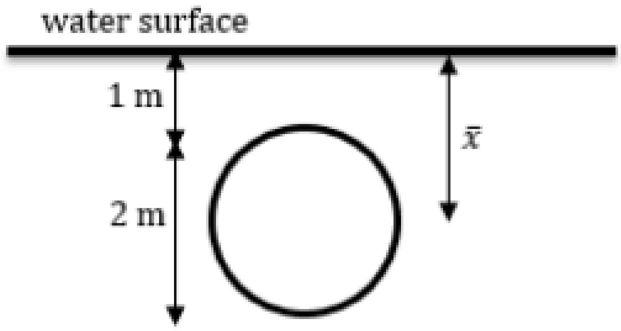
An isosceles triangular plate of base 3 metres and altitude 3 metres is immersed vertically in water as shown in figure below. Determine the total pressure and centre of pressure of the plate.

(ans; 44.1 kN, 1.5 m)



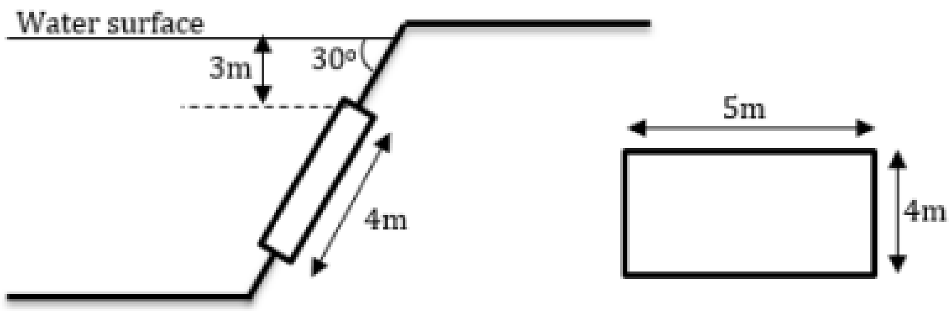
A circular plate of diameter 2 m is submerged in water vertically such that its top surface is 1 m below the free surface of the water. Determine the total pressure force on the plate and the position of the centre of pressure.

ans; 61638.19 kN, 2.125 m)



By refering to the water gate as shown in figure below, calculate the height from the centre of gravity to the water surface. (dis 12)

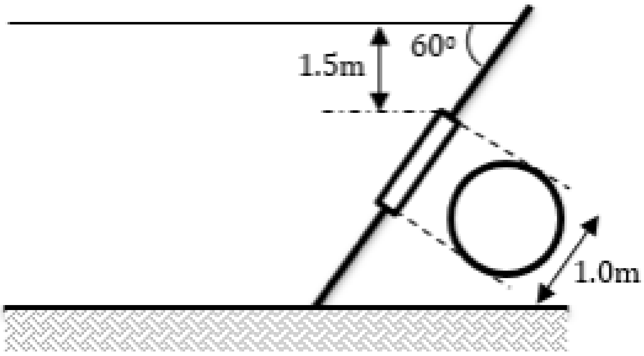
(ans; 4 m)



REVIEW QUESTIONS

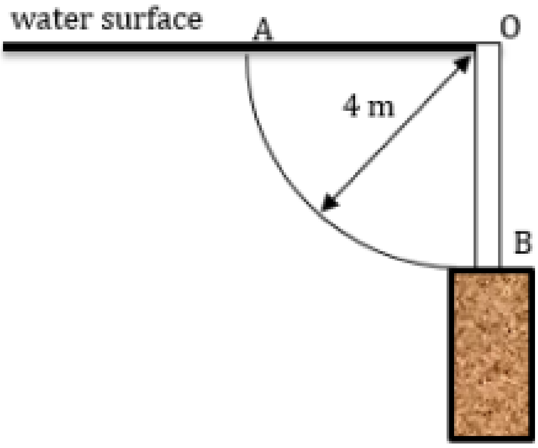
A gate has been installed at inclined outletof water reservoir. This is a rounded door as shown in figure below. Calculate the total of hydrostatic force F, and determine the location for the center of pressure against the door. (dis 13)

(ans; 14885.74 N, 1.957 m)



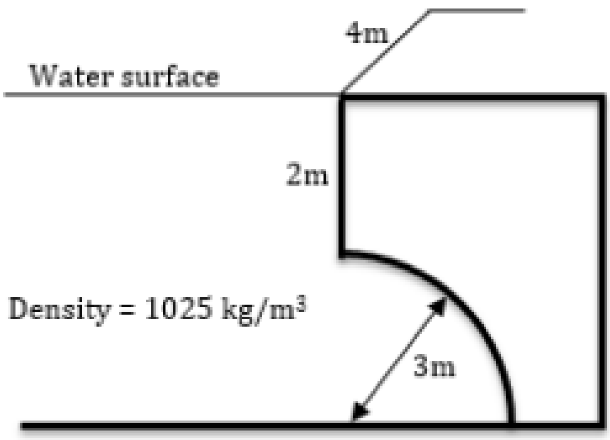
Find the horizontal and vertical forces on a curved surface AB, which is in the form of a quadrant of a circle as shown in figure below. The width of the gate is 3 m.

(ans; 235.44 kN, 369.817 kN)



A curved water gate with 3 m radius as shown in figure below. Calculate the resultant force and the direction of resultant force due to the action of the sea water. Assume the width of the water gate is 4 m and the density of sea water is 1025 kg/m³. (jun14)

(529291.48N, 37.07º)



SUMMARY

The position of the submerged plane surface may be;

HORIZONTAL SURFACE

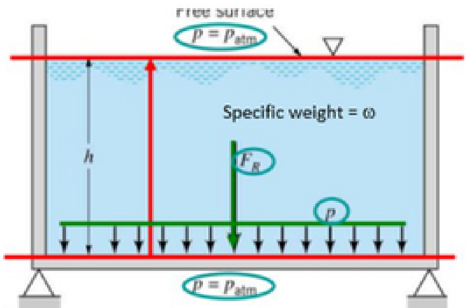
For horizontal surface, the equations for incline
surface can be used where θ = 0.

For example, the bottom of a tank.

Resultant Force, F_R

$$F_R = \rho g h_{cg} A$$

where;
ρ = the density of the liquid (kg/m^3)
g = acceleration due to gravity (kg.m/s^2)
A = area of the submerged surface(m^2)
hcg = height from the fluid surface to the center of gravity of the submerged plane surface (m)



VERTICAL SURFACE

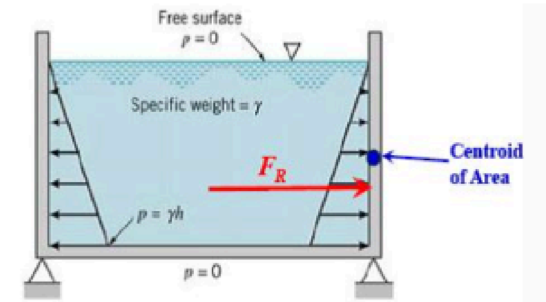
For vertical surface, the equations for incline
surface can be used where θ = 90.

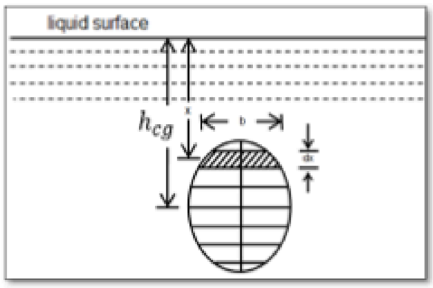
Resultant Force, F_R

$$F_R = \rho g h_{cg} A$$

Height of centre of pressure

$$h_{cp} = \frac{I_c \sin^2\theta}{A\, h_{cg}} + h_{cg}$$





INCLINED SURFACE

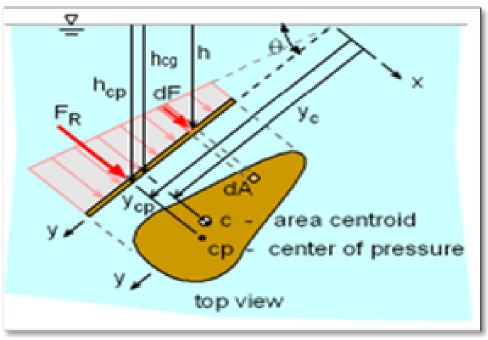
An inclined immersed plane surface, is as shown in
the following figure.

Resultant Force, F_R

$$F_R = \rho g h_{cg} A$$

Height of centre of pressure

$$h_{cp} = \frac{I_c \sin^2\theta}{A\, h_{cg}} + h_{cg}$$



SUMMARY

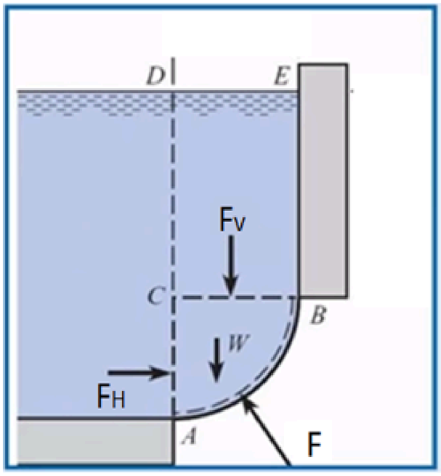
CURVED SURFACE

H is the force equivalent to the force acting on the ertical plane surface projected from the curved urface (the rectangular image).

Horizontal Force, F_H

$$F_H = \rho g h_{cg} A$$

A = heigth of CA x width of gate
= h x L



FV is the force equivalent to the weight of the fluic above the curved surface.

Vertical Force, F_V

$$F_V = \rho g V$$

$$V = V_1 + V_2$$

$$V_1 = w \; x \; h \; x \; L$$

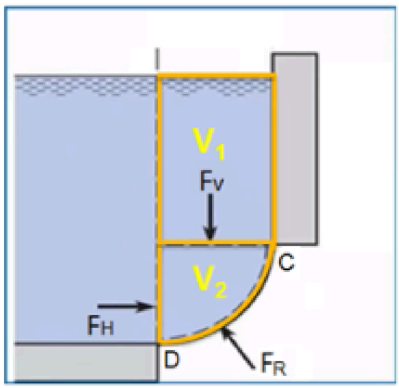
$$V_2 = \frac{\pi (r)^2}{4} \; x \; L$$

where:

ρ = the density of the liquid (kg/m^3)

g = acceleration due to gravity ($kg.m/s^2$)

V = fluid volume above the curved surface up to the fluid surface line (m^3)



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Resultant Force, F_R

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F_R act at an angle α from horizontal

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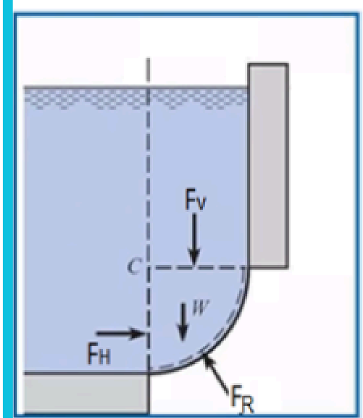

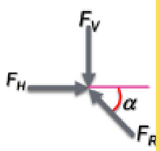

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f) http://www.ignou.ac.in/upload/UNIT%204-BSC-011-BL1.pdf

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