

MECHANICAL ENGINEERING

ESE TOPICWISE
CONVENTIONAL SOLVED PAPER-I

1995-2019



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PREFACE

Engineering Services Exam (ESE) is one of most coveted exams written by engineering students aspiring for reputed posts in the various departments of the Government of India. ESE is conducted by the Union Public Services Commission (UPSC), and therefore the standards to clear this exam too are very high. To clear the ESE, a candidate needs to clear three stages – ESE Prelims, ESE Mains and Personality Test.

It is not mere hard work that helps a student succeed in an examination like ESE that witnesses lakhs of aspirants competing neck to neck to move one step closer to their dream job. It is hard work along with smart work that allows an ESE aspirant to fulfil his dream.

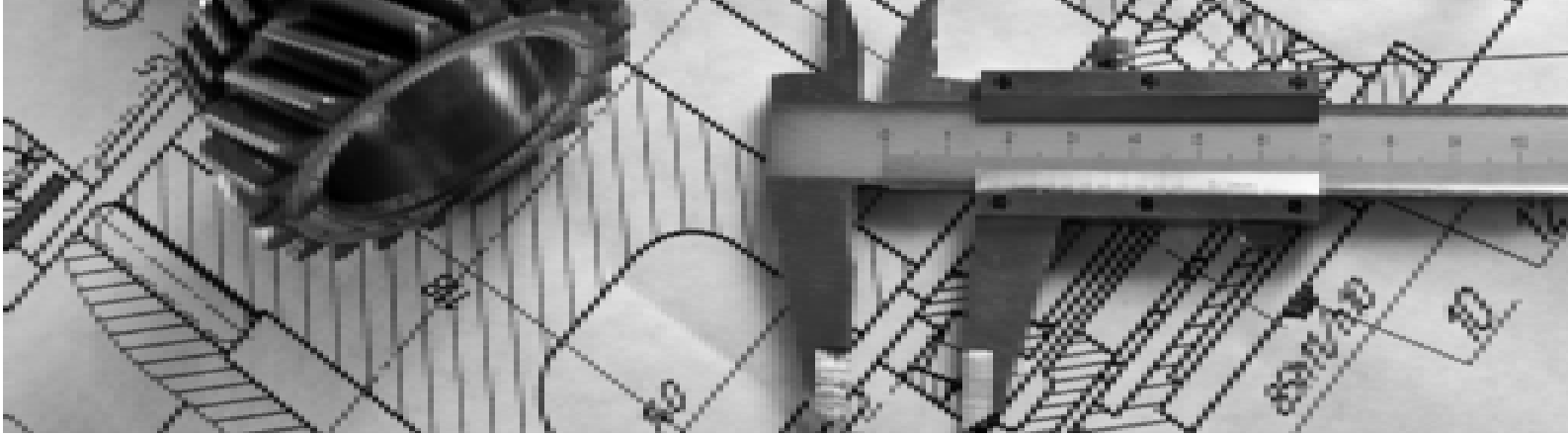
After detailed interaction with students preparing for ESE, IES Master has come up with this book which is a one-stop solution for engineering students aspiring to crack this most prestigious engineering exam. The book includes previous years' solved conventional questions segregated Topicwise along with detailed explanation. This book will also help ESE aspirants get an idea about the pattern and weightage of questions asked in ESE.

IES Master feels immense pride in bringing out this book with utmost care to build upon the exam preparedness of a student up to the UPSC standards. The credit for flawless preparation of this book goes to the entire team of IES Master Publication. Teachers, students, and professional engineers are welcome to share their suggestions to make this book more valuable.

**IES MASTER PUBLICATION
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UNIT-1

FLUID MECHANICS

SYLLABUS

Basic Concepts and Properties of Fluids, Manometry, Fluid Statics, Buoyancy, Equations of Motion, Bernoulli's equation and applications, Viscous flow of incompressible fluids, Laminar and Turbulent flows, Flow through pipes and head losses in pipes. Reciprocating and Rotary pumps, Pelton wheel, Kaplan and Francis Turbines and velocity diagrams.

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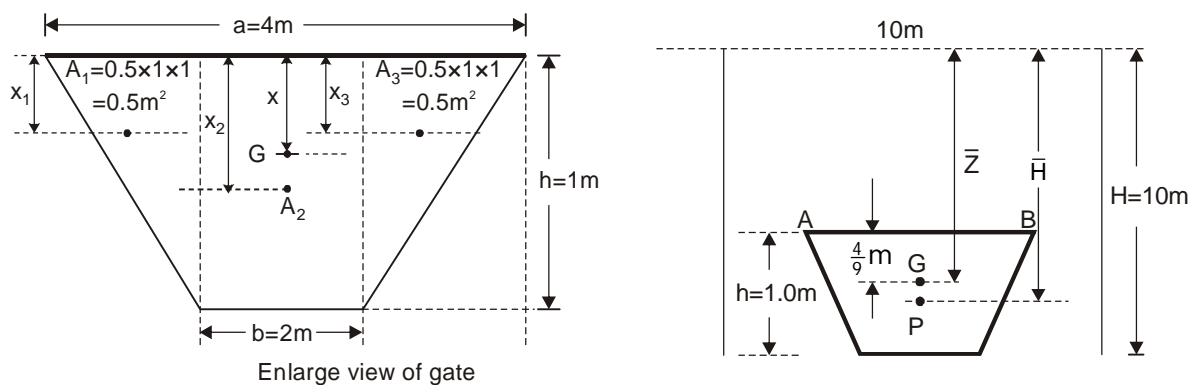
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CHAPTER 1

FLUID STATICS AND BUOYANCY

Q-1: A water storage tank 10 m × 10 m × 10 m has a drainage opening on one of the vertical sides at the bottom which is trapezoidal in shape with a width 2 m at the bottom 4 m at the top and 1 m height. A gate of same dimension hinged along the top edge is used to close it. What is the minimum horizontal force required to be applied at the bottom to keep the gate closed if the tank has full of water in it? Will there be any change in the force required if the tank is only half full? If yes how much? [10 Marks ESE-2014]

Sol: The gate is trapezoidal shape of the following dimensions. A_1 , A_2 and A_3 represent the area of respective portion of gate as shown in figure.



The centroid of trapezoidal gate

$$\bar{x} = \frac{x_1 A_1 + x_2 A_2 + x_3 A_3}{A_1 + A_2 + A_3} = \frac{\frac{1}{3} \times 0.5 \times \frac{1}{2} \times 2 + \frac{1}{3} \times 0.5}{0.5 + 2 + 0.5} = \frac{1 + \frac{1}{3}}{3} = \frac{4}{3 \times 3} = \frac{4}{9} \text{ m}$$

This gate is fitted to a wall of size 10m × 10m as shown in figure.

The depth of centroid of gate from top

$$\bar{Z} = 9 + \frac{4}{9} = \frac{85}{9} \text{ m}$$

The area moment of gate about its centre of gravity,

$$I_G = \frac{(a^2 + 4ab + b^2)}{36(a+b)} \times h^3 = \frac{(4^2 + 4 \times 4 \times 2 + 2^2)}{36 \times (4+2)} \times 1^3 = 0.2407 \text{ m}^4$$

The depth of centre of pressure

$$\bar{H} = \bar{Z} + \frac{I_G}{A \bar{Z}} = \frac{85}{9} + \frac{0.2407 \times 9}{3 \times 85} = \frac{85}{9} + 0.0085 = 9.453 \text{ m}$$

Total pressure force on gate

$$F = \rho g \bar{Z} A = 1000 \times 9.81 \times \frac{85}{9} \times 3 \text{ N} = 278 \text{ kN}$$

Let the applied force at bottom of gate is F_0 , so

$$F_0 = \frac{F \times (\bar{H} - 9)}{(\bar{H} - 9)} = 125.93 \text{ kN}$$

Now the tank is half full,

The centroid,
$$\bar{Z}' = 4 + \frac{4}{9} = \frac{40}{9} \text{ m}$$

Centre of pressure,
$$\bar{H}' = \frac{40}{9} + \frac{0.2407 \times 9}{3 \times 40} = \frac{40}{9} + 0.01805 = 4.4625 \text{ m}$$

Total pressure force,
$$F' = \rho g \bar{Z}' \cdot A = 1000 \times 9.81 \times \frac{40}{9} \times 3 \text{ N} = 130.8 \text{ kN}$$

Now the force to hold the gate,
$$F'_0 = \frac{F' \times (\bar{H}' - 4)}{(\bar{H}' - 4)} = 60.5 \text{ kN}$$

Hence the holding force reduces from 125.93 kN to 60.5 kN.

Q-2: A tank with the vertical sides measuring 3m × 3m contains water to a depth of 1.2 m. An oil of density 900 kg/m³ was poured in the tank up to a depth of 0.8 m. The vertical wall can withstand the trust of 58 kN. Calculate the actual thrust on the wall and centre of pressure. If the oil level is increased up to 0.9 m, what will be stability of the wall? [10 Marks ESE-2012]

Sol: The size of wall is 3m × 3m. Density of oil, $\rho_0 = 900 \text{ kg/m}^3$. Since the oil is lighter than water so it will float on water as shown in figure.

The pressure force due to oil,

$$P_1 = \frac{1}{2} \rho_0 g h \cdot A = \frac{1}{2} \times 900 \times 9.81 \times 0.8 \times 0.8 \times 3 = 8475.84 \text{ N}$$

The increase in pressure force on lower zone i.e. water due to pouring of oil,

$$P_2 = \rho_0 g h \cdot A = 900 \times 9.81 \times 0.8 \times 1.2 \times 3 = 25427.52 \text{ N}$$

The pressure force due to water,

$$P_3 = \frac{1}{2} \rho g h \cdot A = \frac{1}{2} \times 1000 \times 9.81 \times 1.2 \times 1.2 \times 3 = 21189.6 \text{ N}$$

Total pressure force on wall

$$P = P_1 + P_2 + P_3 = 8475.84 + 25427.52 + 21189.6 = 55092.46 \text{ N} = 55.093 \text{ kN}$$

Since the total force is less than critical thrust of 58 kN so the wall is safe.

The centre of pressure from bottom,

$$\begin{aligned} \bar{x} &= \frac{P_3 \times \frac{FD}{3} + P_2 \times \frac{BC}{2} + P_1 \left(BC + \frac{AB}{3} \right)}{P} \\ &= \frac{21189.6 \times 0.4 + 25427.52 \times 0.6 + 8475.84 \times \left(1.2 + \frac{0.8}{3} \right)}{55092.96} \\ &= \frac{36163.6}{55092.86} = 0.6564 \text{ m} \end{aligned}$$

From top of wall = 3 - 0.6564 = 2.3436 m

