IES MASTER PUBLICATION

ESE 2018
UPSC ENGINEERING SERVICES EXAMINATION

MECHANICAL ENGINEERING

ESE SUBJECTWISE
CONVENTIONAL SOLVED PAPER-I

23 YEARS SOLUTION

COMPLETE SOLUTIONS WITH EXPLANATIONS | THOROUGHLY REVISED AND UPDATED

MECHANICAL ENGINEERING

ESE SUBJECTWISE

CONVENTIONAL SOLVED PAPER-I

1995-2017

IES MASTER
PUBLICATION

Office: F-126, (Lower Basement), Katwaria Sarai, New Delhi-110 016
Phone: 011-2652 2064 ▪ **Mobile:** 81309 09220, 97118 53908
Email: info@iesmasterpublications.com, info@iesmaster.org
Web: iesmasterpublications.com, iesmaster.org

IES MASTER PUBLICATION

F-126, (Lower Basement), Katwaria Sarai, New Delhi-110016

Phone : 011-26522064, **Mobile :** 8130909220, 9711853908

E-mail : info@iesmasterpublications.com, info@iesmaster.org

Web : iesmasterpublications.com, iesmaster.org

First Edition : 2017

Typeset at : IES Master Publication, New Delhi-110016

PREFACE

It is an immense pleasure to present topic wise previous years solved paper of Engineering Services Exam. This booklet has come out after long observation and detailed interaction with the students preparing for Engineering Services Exam and includes detailed explanation to all questions. The approach has been to provide explanation in such a way that just by going through the solutions, students will be able to understand the basic concepts and will apply these concepts in solving other questions that might be asked in future exams.

Engineering Services Exam is a gateway to a immensly satisfying and high exposure job in engineering sector. The exposure to challenges and opportunities of leading the diverse field of engineering has been the main reason for students opting for this service as compared to others. To facilitate selection into these services, availability of arithmetic solution to previous year paper is the need of the day. Towards this end this book becomes indispensable.

IES Master Publication

New Delhi

IES MASTER

Institute for Engineers (IES/GATE/PSUs)

ADMISSIONS OPEN

For CE, ME, EE, ECE

SESSION 2018-2019
ESE/GATE/PSUs

Batches start on

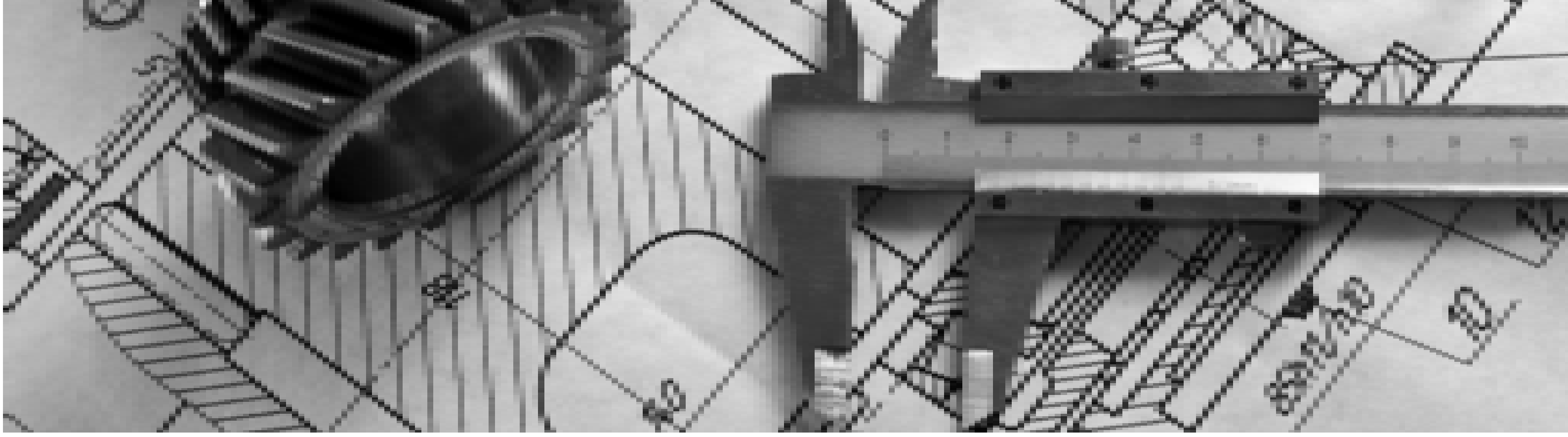
IES Master Delhi Centre

27th Jan / 17th Feb	Weekend Batch (CE/ME/EE/ECE)
12th Feb / 26th Feb	Regular Batch (CE/ME/EE/ECE)

IES Master Noida Centre

27th Jan / 17th Feb	Weekend Batch (CE/ME/EE/ECE)

CONTENTS



UNIT 1 FLUID MECHANICS

SYLLABUS

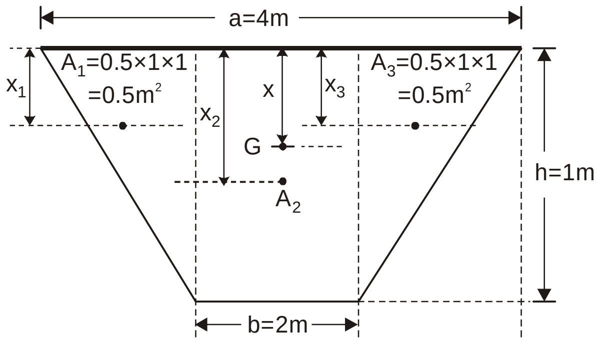
Basic Concepts and Properties of Fluids, Manometry, Fluid Statics, Buoyancy, Equations of Motion, Bernoulli's equation and applications, Viscous flow of incompressible fluids, Laminar and Turbulent flows, Flow through pipes and head losses in pipes. Reciprocating and Rotary pumps, Pelton wheel, Kaplan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

CONTENTS

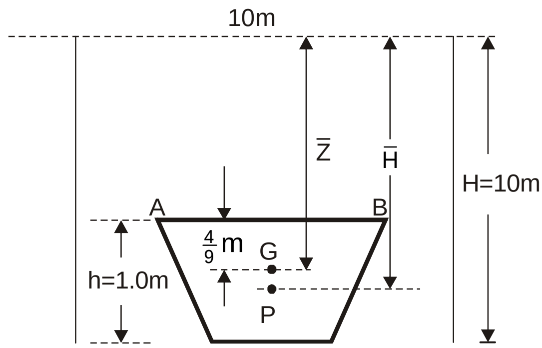
CHAPTER 1 Fluid Statics and Buoyancy

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 by any change in the force required if the tank is only half full? If yes how much?*** ***[10 Marks ESE–2014]***

Sol–1: 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.



Enlarge view of gate



The centroid of trapezoidal gate

$$\bar{x} = \frac{x_1A_1 + x_2A_2 + x_3A_3}{A_1 + A_2 + A_3} = \frac{\frac{1}{3}\times 0.5\times\frac{1}{2}\times 2+\frac{1}{3}\times 0.5}{0.5+2+0.5} = \frac{1+\frac{1}{3}}{3} = \frac{4}{3\times 3} = \frac{4}{9}\text{m}$$

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

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

Now the tank is half full,

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

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

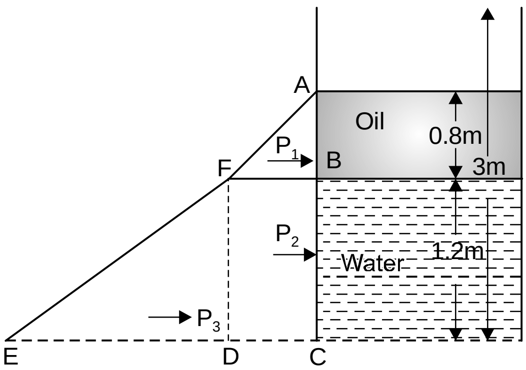
Total pressure force, $F' = \rho g\bar{Z}' \cdot A = 1000 \times 9.81 \times \frac{40}{9} \times 3 \text{ N} = 130.8 \text{ kN}$

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

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 detph 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 Makrs ESE–2012]***

Sol–2: 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,

$$P_1 = \frac{1}{2}\rho_o gh.A = \frac{1}{2} \times 900 \times 9.81 \times 0.8 \times 0.8 \times 3 = 8475.84 \text{N}$$

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

$$P_2 = \rho_0 gh.A = 900 \times 9.81 \times 0.8 \times 1.2 \times 3 = 25427.52 \text{ N}$$

The pressure force due to water,

$$P_3 = \frac{1}{2}\rho gh.A = \frac{1}{2} \times 1000 \times 9.81 \times 1.2 \times 1.2 \times 3 = 21189.6 \text{ N}$$

Total pressure force on wall

$P = P_1 + P_2 + P_3 = 8475.84 + 25427.52 + 21189.6 = 55092.46$ N = 55.093 kN

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

The centre of pressure from bottom,

$$\bar{x} = \frac{P_3 \times \frac{FD}{3} + P_2 \times \frac{BC}{2} + P_1\left(BC + \frac{AB}{3}\right)}{P}$$

$$= \frac{21189.6 \times 0.4 + 25427.52 \times 0.6 + 8475.84 x\left(1.2 + \frac{0.8}{3}\right)}{55092.96}$$

$$= \frac{36163.6}{55092.86} = 0.6564 \text{ m}$$

From top of wall = 3 – 0.6564 = 2.3436 m

Now the depth of oil is increased to 0.9m from 0.8m

$$\therefore \qquad P_{total} = P_1' + P_2' + P_3$$

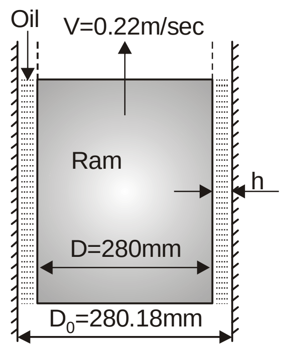
$$= \frac{900 \times 9.81 \times 0.9 \times 0.9 \times 3}{2} + \frac{900 \times 9.81 \times 0.9 \times 1.2 \times 3}{} + 21189.6$$

$$= 10727.235 + 28605.96 + 21189.6 = 60522.795 \text{ N} = 60.523 \text{ kN}$$

This total force is more than critical thrust (58 kN) and the wall will fail.

Q–3: ***A hydraulic lift of the type commonly used for greasing automobiles consists of a 280 mm diameter ram that slides in a 280.18 mm cylinder. The annular space between the ram and cylinder is filled with oil having a kinematic viscosity of 0.00042 m²/s and specific gravity of 0.86. If the rate of travel of the ram is 0.22 m/s, find the frictional resistance when 2m of the ram is engaged in the cylinder.*** ***[5 Marks ESE–2011]***

Sol–3: The schematic of ram in cylinder,



Kinematic viscosity of oil, V = 0.00042 m^2/sec.

Specific gravity, ρ = 0.86

The shear stress,

$$\tau = \mu \cdot \frac{du}{dy} = \mu \frac{(V-0)}{h} = \frac{\mu V}{h} = \frac{0.00042 \times 860 \times 0.22}{0.09 \times 10^{-3}} \text{ N/m}^2 = 882.93 \text{ N/m}^2$$

The force on piston/ram i.e. friction resistance,

$$F = \tau.A = \tau_0 \cdot \pi DL = 882.93 \times \pi \times 0.28 \times 2 = 1553.3 \text{ N}$$

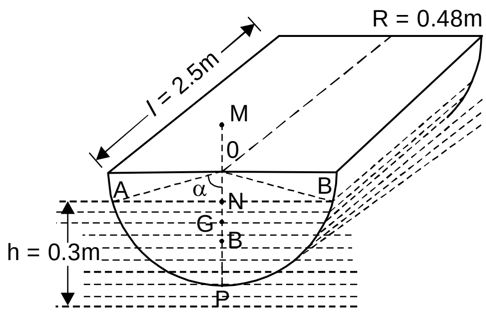
Q–4: ***A solid, half-cylinder-shaped log of 0.48 m radius and 2.5 m long, floats in water with the flat face up.***

(i) ***If the immersion depth of the lowest point is 0.3, what is the uniform specific weight of the log?***

(ii) ***The log tilts about its axis (zero and net applied force), by less than 22°. Is it in stable equilibrium? Justify your answer with a sketch and logic.***

(iii) ***If the log tilts by 18° (left side down; zero net applied force), what is the magnitude and sense of any moment that results?*** ***[15 Marks ESE-2011]***

Sol–4: The half cylinder in water,



Let the specific density of wood is ρ, then in floating condition, Buoyancy force,

$$F_B = W$$

$$\text{Area ABP} \times \text{Length } \rho_0 g = \frac{\pi}{2} R^2 \cdot L \cdot \rho \cdot g$$

$$\text{Area ABP} \times \rho_0 = \frac{\pi}{2} R^2 \rho \qquad \text{...(i)}$$

The area ABP is required to be calculated separately as

$$\text{Area ABP} = \text{Area OAPBO} - \text{Area OAB}$$

$$= \frac{2\alpha}{2\pi}(\pi R^2) - 2 \times \text{Area of triangle OAN}$$

$$= \alpha R^2 - 2 \times \frac{1}{2} \text{AN} \cdot \text{ON}$$

where, $\cos\alpha = \frac{ON}{AO} = \frac{R-h}{R} = 1-\frac{h}{R} = 1-\frac{0.3}{0.48}$

$\alpha = 68^o$

$\therefore$ Area ABP $= 68\times\frac{\pi}{180}\times 0.48^2 - 2\times\frac{1}{2}\times OA\sin\theta\cdot ON$

$= 1.187 \times 0.482 - 0.48 \times \sin 68 \times (0.48–0.3)$

$= 0.27344 - 0.080107 = 0.1933 m^2$

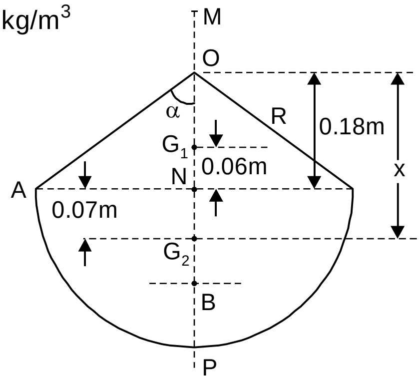
From equation (i),

$$0.1933 \times 1000 = \frac{\pi}{2}0.48^2\rho$$

$$\rho = \frac{193.3\times 2}{\pi\times 0.48^2} = 534.12 \text{ kg/m}^3$$

Density of wood, $\rho = 534.1$ kg/m^3

Specific density $= 0.5341$



Distance of centre of Gravity of log cross-ections

$$OG = \frac{4R}{3\pi} = \frac{4\times 0.48}{3\times\pi} = 0.204\text{m}$$

The location of centre of Buoyancy (B) is centre of gravity of log cross-section inside water (B).

So, location of centre of gravity of cross-section OABP (OG_2) as,

$$\because \quad x = \frac{2}{3}R\frac{\sin\alpha}{\alpha} = \frac{2}{3}\times\frac{0.48\times\sin 68}{1.187} = 0.25 \text{ m}$$

$\because$ $NG_2 = OG_2 - ON = x - ON = 0.25 - 0.18 = 0.07$m

Now to get location of centre of Buoyancy 'B' inside cross section. Take the moment of areas OAB and ABG about G_2.

$$\therefore \quad BG_2 = \frac{\text{Area of OAB}\times G_1G_2}{\text{Area ABP}} = \frac{\text{Area OAB}\times(NG_1+NG_2)}{\text{Area ABP}}$$

$$= \frac{0.18\times 0.48\sin 68\times(0.06+0.07)}{0.1933} = 0.054\text{m}$$

$\because$ Distance of centre of Buoyancy from plane surface of log,

$OB = ON + NG_2 + G_2B$

$= 0.18 + 0.07 + 0.054 = 0.304$ m

$\therefore$ Distance between centre of gravity 'G' and centre of Buoyancy, B

$GB = OB - OG = 0.304 - 0.204 = 0.1$ m

Moment of area of surface of log in the plane of water.

$$I = \frac{1}{12}\cdot L\times AB^3 = \frac{1}{12}\times 2.5\times(2\times R\sin 68)^3 = 0.147 \text{ m}^4$$

Volume of displaced liquid,

V = Area ABP × length

$= 0.1933 \times 2.5 = 0.48325$ m^3

$\therefore$ Metacentric hight $GM = BM - GB = \frac{I}{V} - GB = \frac{0.147}{0.48325} - 0.1$

$= 0.3042 - 0.1 = 0.2042$ m

IES MASTER PUBLICATION

F-126 (Lower Basement), Katwaria Sarai, New Delhi-110016

Phone : 011 26522064, **Mobile :** 97 1185 3908

E-mail : info@iesmasterpublications.com, info@iesmaster.org

Web : iesmasterpublications.com

₹ 775.00

ISBN 978-93-86383-58-7

9789386383587