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IES | GATE | PSU

FLUID MECHANICS

For

MECHANICAL ENGINEERING

CIVIL ENGINEERING

FLUID MECHANICS

SYLLABUS

Fluid properties; fluid statics, manometry, buoyancy, forces on submerged bodies, stability of floating bodies; control-volume analysis of mass, momentum and energy; fluid acceleration; differential equations of continuity and momentum; Bernoulli's equation; dimensional analysis; viscous flow of incompressible fluids, boundary layer, elementary turbulent flow, flow through pipes, head losses in pipes, bends and fittings.
Turbomachinery: Impulse and reaction principles, velocity diagrams, Pelton-wheel, Francis and Kaplan turbines.

ANALYSIS OF GATE PAPERS

MECHANICAL			
Exam Year	1 Mark Ques.	2 Mark Ques.	Total
2003	1	6	13
2004	2	9	20
2005	1	3	7
2006	3	7	17
2007	3	7	17
2008	1	5	11
2009	-	7	14
2010	4	3	10
2011	1	3	7
2012	3	2	7
2013	2	2	6
2014 Set-1	1	5	11
2014 Set-2	2	3	8
2014 Set-3	3	3	9
2014 Set-4	2	2	6
2015 Set-1	1	4	9
2015 Set-2	2	2	6
2015 Set-3	2	2	6
2016 Set-1	3	3	9
2016 Set-2	2	3	8
2016 Set-3	3	3	9
2017 Set-1	4	3	10
2017 Set-2	4	3	10

CIVIL			
Exam Year	1 Mark Ques.	2 Mark Ques.	Total
2003	3	8	19
2004	6	10	26
2005	3	7	17
2006	3	7	17
2007	2	7	16
2008	1	7	15
2009	1	3	7
2010	3	2	7
2011	3	2	7
2012	3		3
2013	3	2	7
2014 Set-1	2	7	16
2014 Set-2	2	4	10
2015 Set-1	3	4	11
2015 Set-2	3	3	9
2016 Set-1	1	3	7
2016 Set-2	1	3	7
2017	1	2	5

CONTENTS

1 BASICS OF FLUID MECHANICS

1.1 DEFINITION OF FLUID

Fluid mechanics deals with the behaviour of fluids at rest and in motion. A fluid is a substance that deforms continuously under the application of a shear (tangential) stress no matter how small the shear stress may be.
Fluids comprise the liquid and gas (or vapour) phases of the physical forms in which matter exists. The distinction between a fluid and the solid state of matter is clear if you compare fluid and solid behaviour. A solid deforms when a shear stress is applied, but its deformation does not continue to increase with time.

1.2 BASIC EQUATIONS

Analysis of any problem in fluid mechanics necessarily begins, either directly or indirectly, with statements of the basic laws governing the fluid motion. The basic laws, which are applicable to any fluid, are:

1. The conservation of mass
2. Newton's second law of motion
3. The principle of angular momentum
4. The first law of thermodynamics
5. The second law of thermodynamics

Clearly, not all basic laws always are required to solve any one problem. On the other hand, in many problem it is necessary to bring into the analysis additional relations, in the form of equations of state or conservation equations, that describe the behaviour of physical properties of fluid under given conditions.

1.3 SYSTEM AND CONTROL VOLUME

A system is defined as a fixed, identifiable quantity of mass; the system boundaries separate the system from the surroundings. The boundaries of the system may be fixed or movable; however, there is no mass transfer across the system boundaries. In the familiar piston –cylinder assembly the gas in the cylinder is the system. Heat and work may cross the boundaries of the system, but the quantity of the matter within the system boundaries remains fixed. There is no mass transfer across the system boundaries.
A control volume is an arbitrary volume in space through which fluid flows. The geometric boundary of the control volume is called the control surface. The control surface may be real or imaginary; it may be at rest or in motion.

GATE QUESTIONS

Topics **Page No**

1 FLUID PROPERTIES

Q.1 The SI unit of kinematic viscosity (v) is
a) m^2/s b) kg/m-s
c) m/s^2 d) m^3/s^2
[GATE–2001]

Q.2 For a Newtonian fluid
a) Shear stress is proportional to shear strain
b) Rate of shear stress is proportional to shear strain
c) Shear stress is proportional to rate of shear strain
d) Rate of shear stress is proportional to rate of shear strain
[GATE–2006]

Q.3 Assuming constant temperature condition and air to be an ideal gas, the variation in atmospheric pressure with height calculated from fluid statics is
a) linear b) exponential
b) quadratic d) cubic

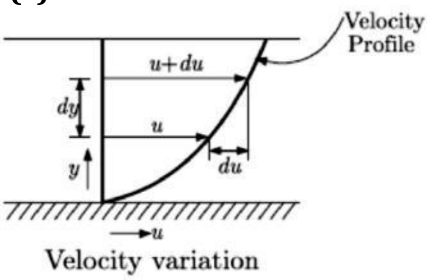
ANSWER KEY:

1	**2**	3
(a)	(c)	(b)

EXPLANATIONS

Q.1 **(a)**

Q.2 **(c)**



Velocity variation near a body

From the Newton's law of Viscosity, the shear stress (τ) is directly proportional to the rate of shear strain (du/dy).

So, $\tau \propto \frac{du}{dy}$ or $\tau = \mu \frac{du}{dy}$

Where μ = Constant of proportionality and it is known as coefficient of Viscosity.

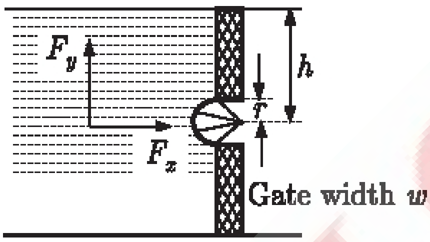
2 FLUID STATICS

Q.1 A static fluid can have

a) non-zero normal and shear stress
b) negative normal stress and zero shear stress
c) positive normal stress and zero shear stress
d) zero normal stress and non-zero shear stress

[GATE–2001]

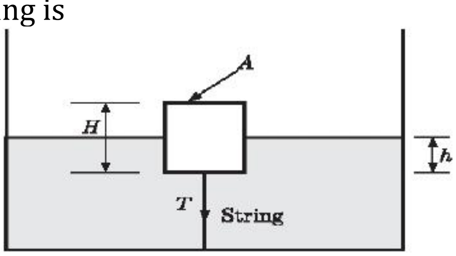
Q.2 The horizontal and vertical hydrostatic forces Fx and Fy on the semi-circular GATE, having a width w into the plane of figure, are



a) $F_x = \rho ghrw$ and $F_y = 0$
b) $F_x = 2\rho ghrw$ and $F_y = 0$
c) $F_x = \rho ghrw$ and $F_y = \frac{\rho gwr^2}{2}$
d) $F_x = 2\rho ghrw$ and $F_y = \frac{\pi\rho gwr^2}{2}$

[GATE–2001]

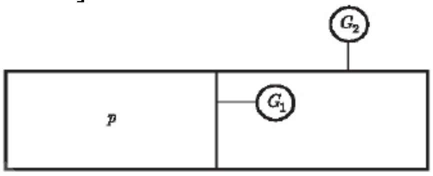
Q.3 A cylindrical body of cross-sectional area A, height H and density ρ_s, is immersed to a depth h in a liquid of density ρ, and tied to the bottom with a string. The tension in the string is



a) ρghA
b) $(\rho_s - \rho)ghA$
c) $(\rho - p_s)ghA$
d) $(\rho h - \rho_s H)gA$

[GATE–2003]

Q.4 The pressure gauges G_1 and G_2 installed on the system show pressure of P_{G1}=5.00 bar and P_{G2}= 1.00 bar. The value of unknown pressure P is [Atmospheric Pressure 1.01 bar]



a) 1.01 bar
b) 2.01 bar
c) 5.00 bar
d) 7.01 bar

[GATE–2004]

Q.5 A closed cylinder having a radius R and height H is filled with oil of density ρ. If the cylinder is rotated about its axis at an angular velocity of ω, the thrust at the bottom of the cylinder is

a) $\pi R^2 \rho gH$
b) $\pi R^2 \frac{\rho\omega^2 R^2}{4}$
c) $\pi R^2(\rho\omega^2 R^2 + \rho gH)$
d) $\pi R^2\left(\frac{\rho\omega^2 R^2}{4} + \rho gH\right)$

[GATE–2004]

Q.6 For the stability of a floating body, under the influence of gravity alone, which of the following is TRUE?

a) Metacenter should be below centre of gravity.
b) Metacenter should be above centre of gravity.
c) Metacenter and centre of gravity must lie on the same horizontal line.
d) Metacenter and centre of gravity must lie on the same vertical line.

[GATE–2010]

EXPLANATIONS

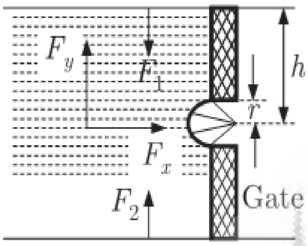
Q.1 **(c)**

Fluid static deals with problems associated with fluids at rest. In static fluid, there is no relative motion between adjacent fluid layers and thus there are no shear (tangential) stresses in the fluid trying to deform it.

The only stress in static fluid is the normal stress, which is the pressure and the variation of pressure is only due to the weight of the fluid and it is always positive.

Therefore, the topic of fluid statics has significance only in gravity field.

Q.2 **(d)**



Here F_1 = weight of water column above the top surface.

F_2 = weight of water column above the bottom surface.

At the depth, pressure is given by

p = ρgh

then horizontal force,

$F_x = A \times p = (2r \times w)\, \rho gh$

where

A = Normal area, when viewed in the direction of F_x

$F_x = 2\rho ghrw$

$F_y = F_2 - F_1$ = weight of water contained in volume of semi circular GATE. $F_y = mg = \left(\frac{\pi}{2} r^2 \times w\right)\rho g$

m = ρV and V = A × w

$$F_y = \frac{\pi \rho g w r^2}{2}$$

Q.3 **(d)**

Given:

Cross section area of body = A

Height of body = H

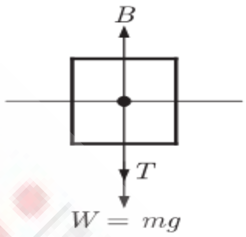
Density of body = ρ_s

Density of liquid = ρ

Tension in the string = T

We have to make the FBD of the block.

B = Buoyancy force



T + mg = ρhAg

$T + \rho_s Vg = \rho hAg$

$T + \rho_s AHg = \rho hAg$

$T = \rho hAg - \rho_s AHg = Ag(\rho h - \rho_s H)$

Q.4 **(d)**

Given: PG1 = 5.00 bar, P_{G2} = 1.01 bar

Absolute pressure of G2

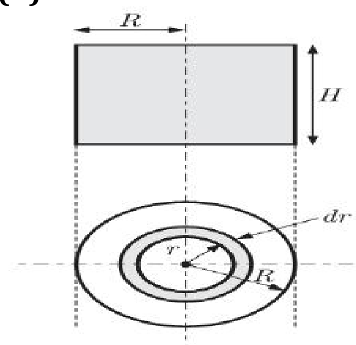
= Atmospheric pressure + Gauge pressure

=1.01 + 1.00= 2.01 bar

Absolute pressure of G_1

= $P_{G1} + P_{abs(G2)}$ = 5.0 + 2.01 = 7.01 bar

Q.5 **(d)**



Total thrust at the bottom of cylinder = Weight of water in cylinder + Pressure force on the cylinder

ASSIGNMENT QUESTIONS

Q.1 What is the dimension of kinematic viscosity of a fluid

a) LT^{-2} b) L^2T^{-1}
c) $ML^{-1}T^{-1}$ d) $ML^{-2}T^{-2}$

Q.2 The general form of expression for the continuity equation in a Cartesian co-ordinate system for incompressible or compressible flow is given by

a) $\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$

b) $\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0$

c) $\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0$

d) $\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=1$

Q.3 Point of application of a horizontal force on a curved surface submerged in liquid is

a) $\frac{I_G}{A\bar{h}}-\bar{h}$ b) $\frac{I_G+A\bar{h}^2}{A\bar{h}}$
c) $\frac{A\bar{h}}{I_G}+\bar{h}$ d) $\frac{I_G}{A\bar{h}}+A\bar{h}$

Q.4 The resultant pressure on a body immersed in a fluid is called

a) Fluid pressure b) Up thrust
c) Buoyancy d) Gravity

Q.5 The center of pressure of a surface subject to fluid pressure is the point

a) On the surface at which resultant pressure acts
b) On the surface at which gravitational force acts
c) At which all hydraulic forces meet
d) Similar to metacenter

Q.6 An odd shaped body weighing 7.5 kg and occupying $0.01m^3$ volume will be completely submerged in a fluid having specific gravity of

a) 1 b) 1.2
c) 0.8 d) 0.75

Q.7 The flow profile of a fluid depends upon

a) Velocity of the fluid only
b) the diameter of the tube only
c) the Reynolds number
d) the surface roughness

Q.8 Stream line, path line and streak line are identical when the

a) Flow is steady
b) Flow is uniform
c) Flow velocities do not change steadily with time
d) Flow is neither steady nor uniform

Q.9 The convective acceleration of fluid in the x-direction is given by

a) $u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial w}{\partial z}$

b) $\frac{\partial u}{\partial t}+\frac{\partial v}{\partial t}+\frac{\partial w}{\partial t}$

c) $u\frac{\partial u}{\partial x}+u\frac{\partial v}{\partial y}+u\frac{\partial w}{\partial z}$

d) $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}$

Q.10 In a two-dimensional flow of a viscous fluid Couette flow is defined for

a) pressure gradient driven laminar flow between fixed parallel plates
b) pressure gradient driven laminar flow through non-circular duct
c) pressure gradient driven laminar flow through pipe
d) Laminar flow between a fixed and a moving plate

Q.11 Most efficient channel section is

a) half hexagon in the form of trapezoid
b) triangular
c) rectangular
d) semicircular

Q.12 Which one of the following is a typical example of non-Newtonian fluid of Pseudo plastic variety
a) Milk b) Air
c) Water d) Printing ink

Q.13 Match **List-I** (Physical properties of fluid) with **List-II** (Dimensions/definitions) and select the correct answer using the codes given below the lists:

List-I
A. Absolute viscosity
B. Kinematic viscosity
C. Newtonian fluid
D. Surface tension

List-II
1. Viscosity is constant
2. Newton per meter
3. Poise
4. Stress/strain is constant
5. Stroke

Codes:

	A	B	C	D
a)	5	3	1	2
b)	3	5	2	4
c)	5	3	4	2
d)	3	5	1	2

Q.14 Capillarity is due to
a) Adhesion of liquid particle to a surface
b) Cohesion of liquid particles
c) Cohesion and Adhesion both
d) Surface tension

Q.15 For a Glass tube of diameter d, height of capillary is given by
a) $\frac{4wd}{\sigma\cos\theta}$ b) $\frac{4\sigma}{wd}\cos\theta$
c) $\frac{4\sigma}{wd\cos\theta}$ d) $\frac{\sigma\cos\theta}{4wd}$
Where,
w= specific weight of liquid
σ= surface tension
θ= angle of contact between liquid and surface

Q.16 The approximate value of θ (angle of contact) for Mercury is
a) 132 b) 182
c) 152 d) None of these

Q.17 What should be the property of a good manometer fluid.
a) low vapour pressure, low density
b) low vapour pressure, high density
c) high vapour pressure, high densit
d) high vapour pressure, low density

Q.18 Fluid is a substance which offers no resistance to change of
a) Volume b) Pressure
c) Shape d) Flow

Q.19 When a piezometer cannot be used for pressure measurement in pipes
a) the pressure difference is low
b) the velocity is high
c) the fluid in the pipe is a gas
d) the fluid in the pipe is highly viscous

Q.20 The instrument preferred in the measurement of highly fluctuating velocities in air flow is
a) Pitot-static tube
b) Propeller type anemometer
c) Three cup anemometer
d) Hot wire anemometer

Q.21 The property by virtue of which a liquid opposes relative motion between its different layers is called
a) Surface tension b) Cohesion
c) Viscosity d) Caillarity

Q.22 The Bulk modulus of elasticity of a fluid is defined as
a) $-\frac{dV/V}{dP}$ b) $-\frac{dP}{dV/V}$
c) $\frac{dP}{dV}$ d) $\sqrt{dP/8d\rho}$

EXPLANATIONS

Q.1 (b)
Unit of kinematic viscosity is m^2/s.
∴Dimension of kinematic viscosity is L^2T^{-1}

Q.2 (c)
The general form of expression for the continuity equation in a Cartesian co-ordinate system

$$\frac{\partial\rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0$$

Q.3 (b)

$$C.P=\frac{I_G}{A\bar{h}}+\bar{h}$$

Wher $\bar{h}$ is distance of centre of gravity from free surface and $\bar{I}_c$ area moment of inertia.

Q.4 (c)

Q.5 (a)
Centre of pressure is defined as the point of application of the total pressure on the surface.

Q.6 (d)

Q.7 (c)
Reynold number is the factor by which type overflows decided i.e. laminar or turbulent.

Q.8 (a)

Q.9 (d)

$$a_x=u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}+\frac{\partial u}{\partial t}$$

Where $u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}$ is the convective acceleration and $\frac{\partial u}{\partial t}$ is the temporal acceleration.

Q.10 (d)
Coutte flow is characterized as flow of very low value of Reynolds number between two parallel plate, one is fixed and other is movable.

Q.11 (a)

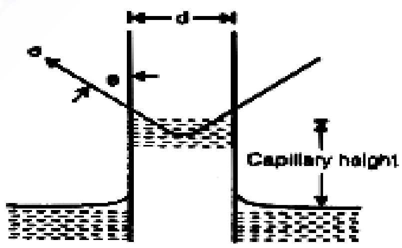
Q.12 (a)

Q.13 (d)

Q.14 (c)

Q.15 (b)
Weight of liquid raised or lowered in the capillary to be = (area of tube × rise or fall) × specific weight

$$=\left(\frac{\pi}{4}d^2h\right)w$$



Vertical components of surface tension force
= σ cos θ ×circumference
= σ cos θ × πd
= π d σ cos θ
In equilibrium, the downward weight of the liquid column h the balanced by the vertical component of the force of surface tension. Hence

$$\frac{\pi}{4}d^2hw=\pi d\sigma\cos\theta$$

Height of capillarity

$$h=\frac{4\sigma}{wd}\cos\theta$$