LECTURE -1

FLUID MECHANICS

UNITS	TOPICS	NO. OF LECTURES
1	**PROPERTIES OF FLUIDS AND FLUID STATICS** **Introduction** : Dimensions and units – Physical properties of fluids - specific gravity, viscosity, surface tension, vapor pressure and their influences on fluid motion, Pressure at a point, Pascal's law, Hydrostatic law - atmospheric, gauge and vacuum pressures. Measurement of pressure, Pressure gauges, Manometers: Simple and differential U-tube Manometers. **Hydrostatic Forces**: Hydrostatic forces on submerged plane, horizontal, vertical, inclined and curved surfaces. Center of pressure, buoyancy	10
2	FLUID KINEMATICS Description of fluid flow, Stream line, path line and streak lines and stream tube. Classification of flows: Steady and unsteady, uniform and non-uniform, laminar and turbulent, rotational and irrotational flows. Equation of continuity for 1 - D, 2 - D, and 3 - D flows – stream and velocity potential functions, flow net	8
3	FLUID DYNAMICS Euler's and Bernoulli's equations for flow along a streamline for 3 - D flow, Navier – Stoke's equations (Explanationary), Momentum equation and its applications. Forces on pipe bend. Pitot-tube, Venturimeter and Orifice meter, classification of orifices, flow over rectangular, triangular, notches, Broad crested weirs	9
4	LAMINAR AND TURBULENT FLOW Reynold's experiment – Characteristics of Laminar & Turbulent flows. Flow between parallel plates, flow through long pipes, flow through inclined pipes. Laws of Fluid friction – Darcy's equation, minor losses, pipes in series and pipes in parallel. Pipe network problems, variation of friction factor with Reynold's number	9
5	BOUNDARY LAYER THEORY Navier-Stoke's Equations, Boundary layer (BL)concepts, Prandtl contribution, Characteristics of boundary layer along a thin flat plate, Vonkarmen momentum integral equation, laminar and turbulent boundary layers (no deriviation), , Drag and Lift forces ,Magnus effect.	8

REFERENCES

1. S.K.Som & G.Biswas, “Introduction to Fluid Machines”, Tata Mc Graw Hill publishers Pvt. Ltd, 2010.
2. Potter, “Mechanics of Fluids”, Cengage Learning Pvt. Ltd., 2001.
3. V.L. Streeter and E.B. Wylie, “Fluid Mechanics”, McGraw Hill Book Co., 1979.
R.K. Rajput, “A Text of Fluid Mechanics and Hydraulic Machines”, S. Chand & company Pvt. Ltd, 6th

INTRODUCTION:

Fluid mechanics may be defined as that branch of Engineering-science which deals with the behaviour of fluid under the conditions of rest and motion.

The fluid mechanics is divided into three parts.

Statics. *The study of incompressible fluids under static conditions is called hydrostatics and that dealing with the compressible static gases is termed as aerostatics.*

Kinematics. *It deals with the velocities, accelerations and the patterns of flow only. Forces or energy causing velocity and acceleration are not dealt under this heading.*

Dynamics. *It deals with the relations between velocities, accelerations of fluid with the forces or energy causing them.*

Fluids properties

The matter can be classified on the basis of the spacing between the molecules of the matter as follows:

1. *Solid state*

2. *Fluid state*

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(i) Liquid state (ii) Gaseous state.

A fluid is a substance which is capable of flowing and deforms continuously when subjected to external shearing force.

A fluid has the following characteristics:

1. *It has no definite shape of its own, but conforms to the shape of the containing vessel.*

2. *Even a small amount of shear force exerted on a liquid/fluid will cause it to undergo a deformation which continues as long as the force continues to be applied.*

A fluid may be classified as follows:

A. *(i) Liquid, (ii) Gas, (iii) Vapour.*

B. *(i) Ideal fluids (ii) Real fluids.*

Liquid

- *A liquid is a fluid which possesses a definite volume (which varies only slightly with temperature and pressure).*
- *Liquids have bulk elastic modulus when under compression and will store up energy in the same manner as a solid. As the contraction of volume of a liquid under compression is extremely small, it is usually ignored and the liquid is assumed to be incompressible. A liquid will withstand a slight amount of tension due to molecular attraction between the particles which will cause an apparent shear resistance, between two adjacent layers and is known as* ***viscosity****.*
- *All known liquids vaporise at narrow pressures above zero, depending on the temperature.*

Gas. *It possesses no definite volume and is compressible.*

Vapour. *It is a gas whose temperature and pressure are such that it is very near the liquid state (e.g., steam).*

Ideal fluids. *An ideal fluid is one which has no viscosity and surface tension and is incompressible. In true sense no such fluid exists in nature. However fluids which have low viscosities such as water and air can be treated as ideal fluids under certain conditions. The assumption of ideal fluids helps*

Real fluids. *A real practical fluid is one which has viscosity, surface tension and compressibility in addition to the density. The real fluids are actually available in nature.*

Continuum. *A continuous and homogeneous medium is called* ***continuum.*** *From the continuum view point, the overall properties and behaviour of fluids can be studied without regard for its atomic and molecular structure.*

Some important properties of water which is as follows:
(i) Density, (ii) Specific gravity, (iii) Viscosity, (iv) Vapour pressure, (v) Cohesion, (vi) Adhesion, (vii) Surface tension, (viii) Capillarity, and (ix) Compressibility.

Density (mass density): *The mass per unit volume is defined as density. The unit used is* kg/m^3. *The measurement is simple in the case of solids and liquids. In the case of gases and vapours it is rather involved. The symbol used is □. The characteristic equation for gases provides a means to estimate the density from the measurement of pressure, temperature and volume.*

specific Volume: *The volume occupied by unit mass is called the specific volume of the material. The symbol used is v, the unit being* m^3/kg. *Specific volume is the reciprocal of density.*

In the case of solids and liquids, the change in density or specific volume with changes in pressure and temperature is rather small, whereas in the case of gases and vapours, density will change significantly due to changes in pressure and/or temperature.

Weight Density or Specific Weight: *The force due to gravity on the mass in unit volume is defined as Weight Density or Specific Weight. The unit used is* N/m^3. *The symbol used is □. At a location where g is the local acceleration due to gravity,*

In the above equation direct substitution of dimensions will show apparent non-homogeneity as the dimensions on the LHS and RHS will not be the same. On the LHS the dimension will be N/m^3 *but on the RHS it is* $kg/m^2\ s^2$. *The use of* g_o *will clear this anomaly. As* *seen in section 1.1, g_o = 1 kg m/N s^2. The RHS of the equation 1.5.1 when divided by g_o will lead to perfect dimensional homogeneity. The equation should preferably be written as,*

(1.5.2)

Since newton (N) is defined as the force required to accelerate 1 kg of mass by 1/s^2, it can also be expressed as kg.m/s^2. Density can also be expressed as Ns^2/m^4 (as kg = Ns^2/m). Beam balances compare the masses while spring balances compare the weights. The mass is the same (invariant) irrespective of location but the weight will vary according to the local gravitational constant. Density will be invariant while specific weight will vary with variations in gravitational acceleration.

***Specific Gravity or Relative Density:** The ratio of the density of the fluid to the density of water—usually 1000 kg/m^3 at a standard condition—is defined as Specific Gravity or Relative Density of fluids. Specific gravity is also equal to the ratio of weight density of the material to the weight density of water. This is a ratio and hence no dimension or unit is involved.*

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VISCOSITY

It is the property of a fluid which determines its resistance to shearing stresses.

Newton's law of viscosity states that the shear stress (τ) on a fluid element layer is directly proportional to the rate of shear strain. The constant of proportionality is called the coefficient of viscosity. Mathematically, $\tau = \mu$,(du/ dy)

where μ = co-efficient of dynamic viscosity, and

(du/dy) = rate of shear deformation or velocity gradient.

Kinematic viscosity is the ratio between the dynamic viscosity and density of fluid. It is denoted by ν (nu). i.e., $\nu = \mu / \rho$

SURFACE TENSION

. Surface tension (ρ) is caused by the force of cohesion at the free surface. It is usually expressed in N/m.

**Pressure inside:*

(a) Water droplet: $p = (4\,\sigma / d)$

(b) Soap bubble : $p = (8\sigma / d)$

(c) Liquid jet: $p = (2\sigma / d)$ (where d stands for diameter).

CAPILLARITY

Capillarity is a phenomenon by which a liquid (depending upon its specific gravity) rises into a thin glass tube or below its general level.

$h = (4\sigma \cos\theta) / wd$, where, h = Height of capillary rise,

d = Diameter of the capillary tube,

θ = Angle of contact of the water surface,

σ = Surface tension per unit length, and

w = Weight density (ρg).

COMPRESSIBILITY

Compressibility is the property by virtue of which fluid undergoes a change in volume under the action of external pressure. It is the reciprocal of bulk modulus of elasticity (K).

K = dp (increase of pressure) / $-(dV/V)$

where (volumetric strain)= $-(dV/V)$

Compressibility = 1/k