Hall Ticket Number: **18ME001**

II/IV B.Tech (Regular) DEGREE EXAMINATION

NOVEMBER, 2019 **ELECTRONICS & INSTRUMENTAION ENGINEERING**

First Semester **Elements Of Mechanical Engineering**

Time: Three Hours Maximum **:** 50 Marks

Answer Question No.1 compulsorily. (1X10 = 10 Marks)

Answer ONE question from each unit. (4X10=40 Marks)

Scheme of evaluation

1M

A)

system error an instruction that is either not recognized by an operating system or is in violati on of theprocedural rules

a change made to something in order to correct or improve it, or the action of making such a change

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b) **1M**

(i) Direct method of measurement.
(ii) Indirect method of measurement.
(iii) Fundamental method of measurement.
(iv) Comparison method of measurement
(v) Transposition method of measurement.
(vi) Differential or comparison method of measurement

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c) A vehicle **inspection**, e.g., an annual **inspection**, is a necessary **inspection**required on vehicles to conform with laws regarding safety, emissions, or both. It consists of an examination of a vehicle's components, usually done by a certified mechanic. **1M**

1M

d) Generally speaking, a **bearing** is a device that is used to enable rotational or linear movement, while reducing friction and handling stress. Resembling wheels, **bearings** literally enable devices to roll, which reduces the friction between the surface of the**bearing** and the surface it's rolling over.

1M

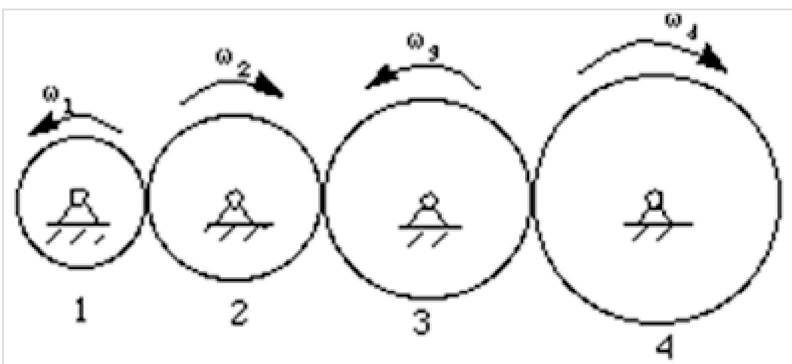
e) The simple gear train is used where there is a large distance to be covered between the input shaft and the output shaft. Each gear in a simple gear train is mounted on its own shaft.

When examining simple gear trains, it is necessaryto decide whether the output gear will turn faster, slower, or the same speed as the input gear. The circumference (distance around the outside edge) of these two gears will determine their relative speeds.

Suppose the input gear's circumference is larger than the output gear's circumference. The output gear will turn faster than the input gear. On the other hand, the input gear's circumference could be smaller than the output gear's circumference. In this case the output gear would turn more slowly than the input gear. If the input and output gears are exactly the same size, they will turn at the same speed.

In many simple gear trains there are several gears between the input gear and the output gear.

These middle gears are called idler gears. Idler gears do not affect the speed of the output gear.



1M

f) A **thermodynamic cycle** is a series of **thermodynamic**processes which returns a system to its initial state. Properties depend only on the **thermodynamic** state and thus do not change over a **cycle**. Variables such as heat and work are not zero over a **cycle**, but rather depend on the process.

1M

g) **Steady flow process** is a **process** where: the fluid properties can change from point to point in the control volume but remains the same at any fixed point during the whole **process**. A **steady-flow process** is characterized by the following: No properties within the control volume change with time

1M

h) **Mass density** represents the **mass** (or number of particles) per unit volume of a substance, material or object. ... **Mass density**is a quantitative expression of the amount of **mass** contained per unit volume. The standard unit is kilograms per meter cubed (kg/m3).

1M

i) A Hydrostatics Law state that rate of increase of pressure in a vertically downward direction in fluid/liquid is equal to weight density of the liquid

1M

j) The flow must be steady, i.e. the fluid properties (velocity, density, etc...) at a point cannot change with time.

The flow must be incompressible – even though pressure varies, the density must remain constant along a streamline.

Friction by viscous forces has to be negligible

2 a) 5M

Differentiate between Line and End Standards

Sl No	Characteristics	Line Standard	End Standard
1	Principal	Length is expressed as distance b/w 2 lines	Length is expressed as distance b/w 2 ends
2	Accuracy	Ltd to +/- 0.2mm	Highly accurate of closed tolerance to +/- 0.001 mm
3	Ease	Quick and easy	Time consuming and requires skill
4	Effect of wear	wear at only the ends	wears at measuring surface
5	Alignment	cannot be easily aligned	easily aligned
6	cost	low cost	high cost
7	Parallax effect	Subjected to parallax effect	Not Subjected to parallax effect

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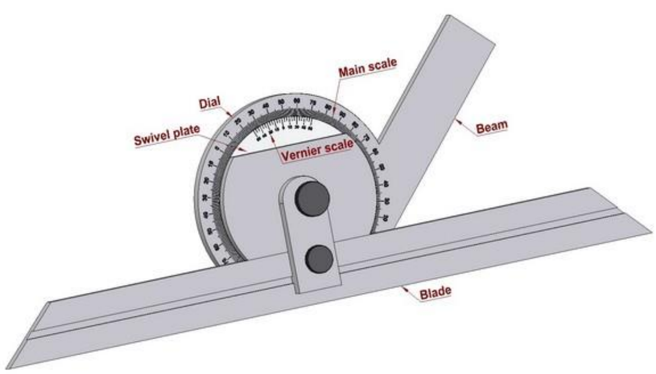
5M

2b) These varieties include **angular** separation of bounding planes, **angular** spacing conditions related to circle, digression from a basic direction etc. Because of these diverse geometrical forms, **different types** of methods and equipment are available to **measure angles** in common **angular** units of degree, minute and second



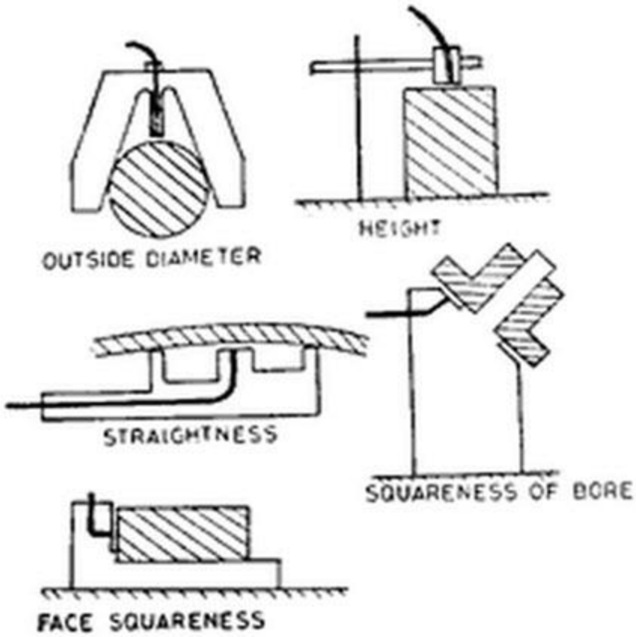
It is probably the simplest instrument for measuring the angle between two faces of component. It consists of a base plate attached to the main body, and an adjustable blade which is attached to a circular plate containing vernier scale. The adjustable blade is capable of rotating freely about the centre of the main scale engraved on the body of the instrument and can be locked in any position. An acute angle attachment is provided at the top ; as shown in Fig. 8.1 for the purpose of measuring acute angles. The base of the base plate is made flat so that it could be laid flat upon the work and any type of angle measured. It is capable of measuring from 0 to 360°. The vernier scale has 24 divisions coinciding with 23 main scale divisions. Thus the least count of the instrument is 5′. This instrument is most commonly used in workshops for angular measurements till more precision is required. A recent development of the vernier bevel protractor is optical bevel protractor. In this instrument, a glass circle divided at 10′ intervals throughout the whole 360° is Fitted inside the mam body. A small microscope is fitted through which the circle graduations can be viewed. The adjustable blade is clamped to a rotating member which carries this microscope. With the aid of microscope it is possible to read by estimation to about2′.

Applications : They are used for a variety of mechanical and engineering-related applications, but perhaps the most common use is in geometry lessons in schools. Some protractors are simple half-discs. More advanced protractors, such as the bevel protractor, have one or two swinging arms, which can be used to help **measure** the angle.

3 a) 5M

Pneumatic Comparator

The working principle of pneumatic comparator is, when the air under constant pressure discharges by passing through two openings. If one of the hole is kept uniform, the pressure will change according to the size of the other. In the following diagram, the tube 1is connected to an air supply & via restriction jets2 to pipe 11 which dips into water in a deep vessel open to the atmosphere. Air flowing at tube 1 increases in pipe 11 and keeps a fixed head of water-H and extra of air outflows as bubbles. Air from pipe11 flows through control jet3 & finally outflows through the measuring jet at 6.



Pneumatic Comparator

The pressure in the tube b/n control jet 3 and calculating jet6 will depend on the orifice size at 6, which is controlled by the distance b/n the measuring table and face, and is replicated by the height of a liquid in the manometer pipe8. The scale 9 is also adjusted that a head difference h specifies changes in the gap d enlarged various hundred times. The main advantages of this comparator is, easy to operate, cheap, independent of the constant pressure, free from mechanical wear and magnification is high as 10,000 times.

Thus, this is all about a comparator and the types of comparators which includes mechanical, optical, Reed type, electrical and pneumatic comparators.

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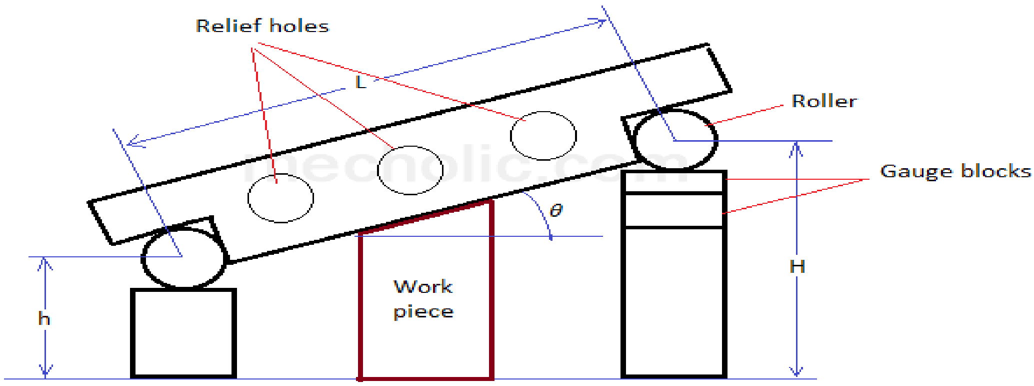
3 b) **5M**

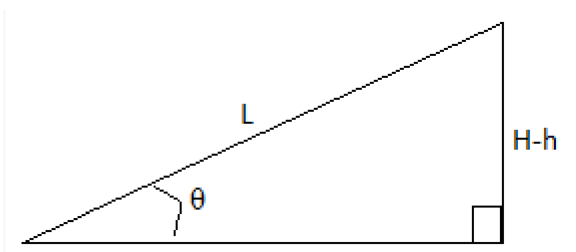
Sine bar consists of a precisely machined corrosion resistant chrome steel. It is essentially hardened and stabilized. It is resting on two identical hardened steel rollers. The distance between the centers of these rollers precisely controlled, this dimension is chosen to be a whole number (200mm, 250mm, 300mm, etc.) for easiness of angle calculation (this dimension becomes the hypotenuse in the calculation).

The relief holes are drilled into the body of sine bar to reduce the weight, and to facilitate handling. Sine bar comes in different lengths, shape or design for the different application, but their principle is same.



The above fig shows the simplest arrangement of sine bar. To measure the angle a wedge is placed on flat surface. Sine bar is positioned on the wedge as shown in fig. Sine bar is supported

on the roller on the gauge block. The top surface will incline the same angle as in the wedge. Now the sine of angle is equal to the ratio of the perpendicular distance between the rollers (H-h) to the horizontal distance between roller (length of sine bar, L). This is equivalent to the following figure.



$$sin\ \theta = \frac{H-h}{L}$$

Applications/use of sine bar

Checking flatness of a surface, Locating a work in required angle, Checking angle of taper key, Checking bevel gears

4 a) **5M**

Simple Gear Train-

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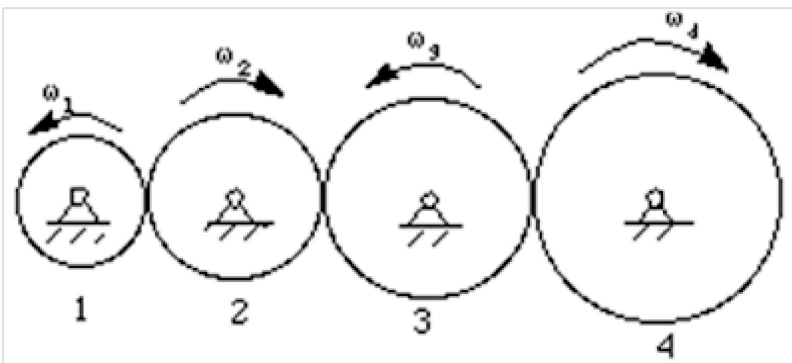


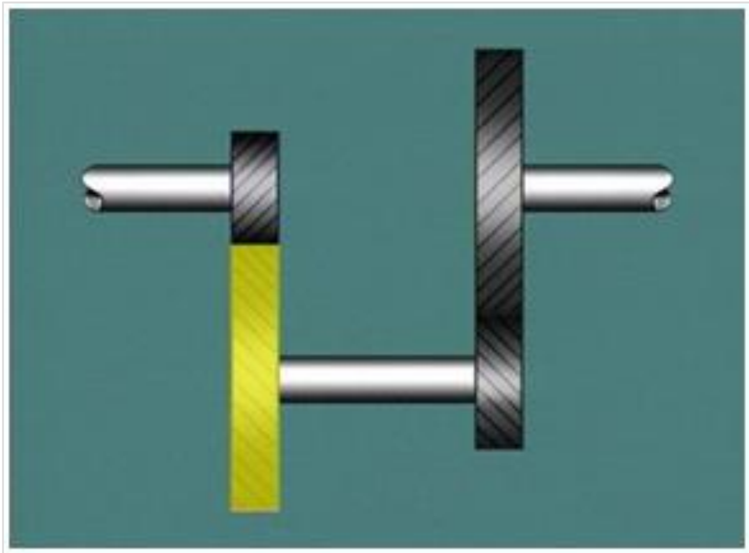
Compound Gear Train-

In a compound gear train at least one of the shafts in the train must hold two gears.

Compound gear trains are used when large changes in speed or power output are needed and there is only a small space between the input and output shafts.

The number of shafts and direction of rotation of the input gear determine the direction of rotation of the output gear in a compound gear train. The train in Figure has two gears in between the input and output gears. These two gears are on one shaft. They rotate in the same direction and act like one gear. There are an odd number of gear shafts in this example. As a result, the input gear and output gear rotate in the same direction.

Since two pairs of gears are involved, their ratios are “compounded”, or multiplied together.



4 b) **5M**

Advantages Of Gear Drive:

- Positive drive and has more efficiency than belt and rope drive.
- Operation of drive is simple and effective.
- Life is more compared to other drives.
- With one input speed, no. of output speeds can be obtained by using suitable gear drive.
- Safe and compact.
- Constant velocity ration is obtained.
- Using different type of gears, power can be transmitted between shafts whose axes are parallel, inclined or intersecting to each other

Disadvantages of Gear Drive:

1. If the tooth geometry of the gear is not properly maintained, the drive may get locked.
2. Not preferred when very high speed transmission is required.
3. If lubrication arrangement is not provided, it may produce noise.

5 a) **5M**

A clearance must be provided at the bottom of the groove, as shown in Fig. (b), in order to prevent touching to the bottom as it becomes narrower from wear. The V-belt drive, may be inclined at any angle with tight side either at top or bottom. In order to increase the power output, several V- belts may be operated side by side. It may be noted that in multiple V-belt drive, all the belts should stretch at the same rate so that the load is equally divided between them. When one of the set of belts break, the entire set should be replaced at the same time. If only one belt is replaced, the new unworn and unstressed belt will be more tightly stretched and will move with different velocity.

Advantages and Disadvantages of V-belt Drive Over Flat Belt DriveAdvantages

1. The V-belt drive gives compactness due to the small distance between the centres of pulleys.

2. The drive is positive, because the slip between the belt and the pulley groove is negligible.

3. Since the V-belts are made endless and there is no joint trouble, therefore the drive is smooth.

4. It provides longer life, 3 to 5 years.

Disadvantages

1. The V-belt drive cannot be used with large centre distances.

2. The V-belts are not so durable as flat belts.

3. The construction of pulleys for V-belts is more complicated than pulleys for flat belts.

4. Since the V-belts are subjected to certain amount of creep, therefore these are not suitablefor constant speed application such as synchronous machines, and timing devices.

5. The belt life is greatly influenced with temperature changes, improper belt tension andmismatching of belt lengths.

6. The centrifugal tension prevents the use of V-belts at speeds below 5 m/s and above 50m/s.

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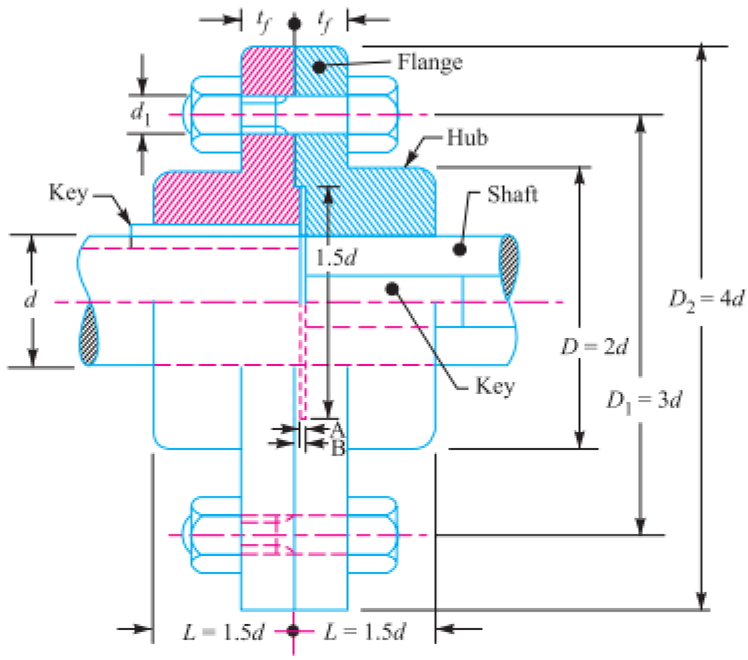
5 b) **5M**

Flange Coupling A flange coupling usually applies to a coupling having two separate cast iron flanges. Each flange is mounted on the shaft end and keyed to it. The faces are turned up at right angle to the axis of the shaft. One of the flange has a projected portion and the other flange has a corresponding recess



This helps to bring the shafts into line and to maintain alignment. The two flanges are coupled together by means of bolts and nuts. The flange coupling is adopted to heavy loads and hence it is used on large shafting. The flange couplings are of the following three types : 1. Unprotected type flange coupling. In an unprotected type flange coupling, as shown in Fig. 13.12, each shaft is keyed to the boss of a flange with a counter sunk key and the flanges are coupled together by means of bolts. Generally, three, four or six bolts are used. The keys are staggered at right angle along the circumference of the shafts in order to divide the weakening effect caused by keyways. The usual proportions for an unprotected type cast iron flange couplings, as shown in Fig. 13.12, are as follows : If d is the diameter of the shaft or inner diameter of the hub, then Outside diameter of hub

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6 a) **5M**

thermodynamic system (or simply 'system') is a definite macroscopic region or space in the universe, in which one or more thermodynamic processes take place.
Everything external to a thermodynamic system is called surroundings. System and surroundings are separated by a definite border called boundary. System, surroundings and boundary constitute the universe.

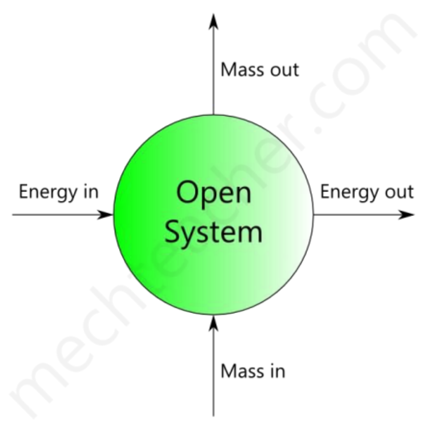
Thermodynamic systems can be broadly classified into three types. They are:

1. [Open System]
2. [Closed System]
3. [Isolated System]

1. Open System:

An open system is a thermodynamic system which allows both mass and energy to flow in and out of it, across its boundary. The image below illustrates open system.

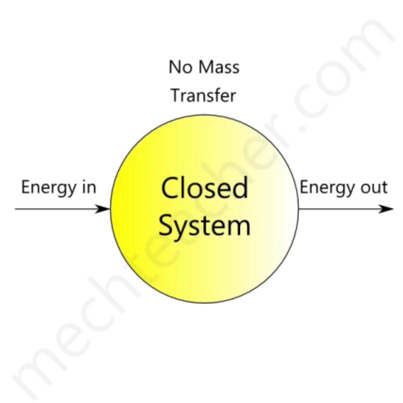
Example of open system: Water heated in an open container – Here, heat is the energy transferred, water is the mass transferred and container is the thermodynamic system. Both heat and water can pass in and out of the container.



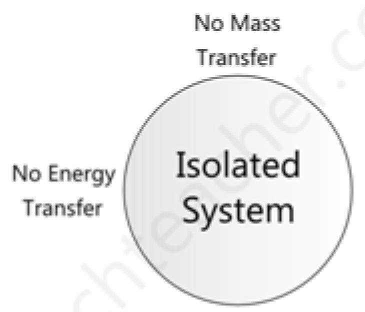
2. Closed System:

A closed system allows only energy (heat and work) to pass in and out of it. It does not allow mass transfer across its boundary. The following image shows a closed system:

Example of closed system: **Water heated in a closed vessel – Here only heat energy can pass in and out of the vessel**



An isolated system does not interact with its surroundings. It does not allow both mass and energy transfer across its boundary. It is more restrictive.In reality, complete isolated systems do not exist. However, some systems behave like an isolated system for a finite period of time. The following image illustrates an isolated system:



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6 b) **5M**

The Zeroth Law of Thermodynamics states that if two bodies are each in thermal equilibrium with some third body, then they are also in equilibrium with each other. Thermal equilibrium means that when two bodies are brought into contact with each other and separated by a barrier that is permeable to heat, there will be no transfer of heat from one to the other.

carnot's theorem

"The efficiency of all reversible engines operating between the same two temperatures is the same, and no irreversible engine operating between these temperatures can have a greater efficiency than this

thermodynamic cycle

A **thermodynamic cycle** is a series of **thermodynamic**processes which returns a system to its initial state. Properties depend only on the **thermodynamic** state and thus do not change over a **cycle**. Variables such as heat and work are not zero over a **cycle**, but rather depend on the process.

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7 a) **5M**

Entropy and disorder

Work is a macroscopic concept. Work involves order or the orderly motion of molecules, as in the expansion or compression of a gas. The kinetic energy and potential energy of a system represent orderly forms of energy. The kinetic energy of a gas is due to the coordinated motion

of all tbe molecules with the same average velocity in the same direction. The potential energy is due ro the vantage position taken by the molecules or displacements of molecules from their normal positions. Heat or thermal energy is due to the random thermal moti.on of molecules in a completely disorderly .fashion and tbe average velocity is ze.ro. Orderly energy cao be readily converted into dis.orderly energy. e.g., mechanical and electrical energies into internal energy (and then heat) by friction and Jou.le effect. Orderly energy can also be convened into one another. But there are nmural limitatio11s on the conversi<m of disorderly energy imo
orderly energy. as delineated by the sec(lt1d law. When work is dissipated into inte.mal energy, the disorderly motion of molecules is increased. Two gases, when mixed, represent a higher degree of disorder than when they are separated. An irreversible process always tends to take the system (isolated) to a state of greater disorder. It is a tendency oo the part of nature to proceed to a state of greater disorder. An isolated system always tends to a state of greater entropy. So there is a close link between entropy and disorder. It may be stated roughly
that the entropy of a system is a measure of the degree of molecular disorder exi.fting in the system. When heat is imparted to a system, the disorderly motion of molecules increases, and so the entropy of the system increases. The reverse occurs when heat is removed from the system. Ludwig Boltzmann (1877) introduced statistical concepts to define disorder by attaching to each state a thermodynamic probability, expressed by the quantity rv; which is greater the more
disordered the state is. The increase of entropy .implies tha.1 the system proceeds by itself from one state to another with a higher them1odynamic probability (or disorder number). An irreversible process goes on until the most probable state (equHibrium state when Wis maximum) corresponding to the maximum value of entropy is reached. Boltzmann assumed a functional relation between S and W. While entropy is additive, probability is multiplicative. If the two parts A and B of a system in equilibrium are considered, the entropy is the sum

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7 b) **5M**

First Law for a Closed System Undergoing a Cycle The traru.ferofheat and the performance of work may both cause the same effect in a system. Heat and work are different forms of.the same entity, called energy, which is conserved. Energy which enters a system as heat may leave the system as work, or energy which enters the system as work may leave as beat. Let us consider a closed system which consists of a known mass of water contained in an adiabatic vessel having a thermometer and a paddle wheel, as shown in.Fig. 4.1. Let acerfai..o amount ofwork W1 _2 be done upon the system by the paddle wheel. The quantity of work can be measured by the fall of weight which drives th.c paddle wheel through a .Pulley. The system was initially at temperature 11, the same as that of atmosphere, and after work transfer let the temperature rise to t2. The pressure is always I atrn. The process 1-2 undergone by lhe system is shown in Fig. 4.2 in generalized thermodynamic coordinatesX, Y. Let the insulation now be removed. Tbe system and the surroundings interact by heat transfer till the system returns to the original temperature t 1, attaining the condition of thennal equilibrium with the atmosphere. The amount ofheat transfer Q2_1 from the system during this process, 2-1, shown in Fig. 4.2, can be estimated. The system thus executes a cycle, which consists of a definite amount of work input W1 _2 to the system followed by the transfer of an amount of heat Q2_1 from the system. It has been found that this

W1_2 is always proportional to the beat Q2-1, and the constant of proportionality is called the Joule's equivalent

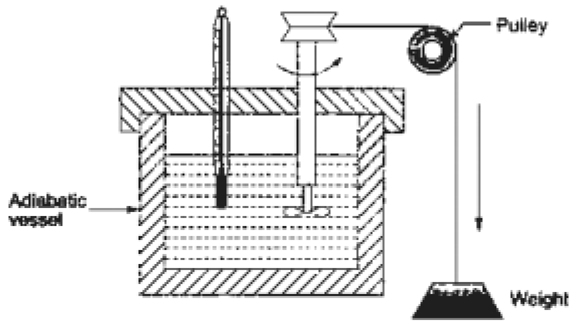


Fig. 4.1 *Adiabatic work*

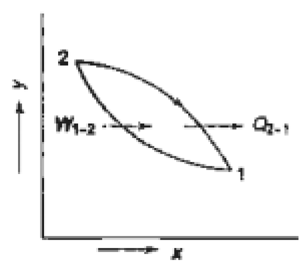
or the mechanical equivalent of heat. In the simple example given here, there are only two energy transfer quantities as the system performs a thermodynamic cycle. If the. cycle involves many more beat and work quantities, the same result will be found.

$$(\Sigma W)_{cycle} = J(\Sigma Q)_{cycle}$$

where J is the Joule's equivalent. This is also expressed in the form

$$\oint dW = J \oint dQ$$

where lhc symbol f denotes the cyclic integral for the closed path. This is the first law for a closed system undergoing a cycle. It is accepted as a general law of nature, since no violation of it has ever been demonstrated. In the S.I. system of units, bolh heat and work are measured in lhe derived unit of energy, the Joule. The constant of proportionality, J, is therefore unity (J= I Nm/J). The first law of thennodynamics owes much to J.P. Joule who, during the period 1840-1849, carried out a series of experiments to investigate the equivalence of work and heat. ln one of these experiments, Joule used an apparatus similar to the one shown in Fig. 4.1. Work was transferred to the



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8 a) **5M**

Specific Gravity:

Specific gravity is the ratio of specific weight of the given fluid to the specific weight of standard fluid. It is denoted by the letter ‘S’. It has no unit.

$$\text{Specific Gravity, S} = \frac{\text{Specific Weight of Given Fluid}}{\text{Specific Weight of Standard Fluid}}$$

Specific gravity may also be defined as the ratio between density of the given fluid to the density of standard fluid.

$$S = \frac{\rho_{\text{given fluid}}}{\rho_{\text{standard fluid}}}$$

Viscosity

Viscosity is the fluid property that determines the amount of resistance of the fluid to shear stress. It is the property of the fluid due to which the fluid offers resistance to flow of one layer of the fluid over another adjacent layer.In a liquid, viscosity decreases with increase in temperature. In a gas, viscosity increases with increase in temperature.

Surface Tension (σ): When a liquid and gas or two immiscible liquids are in contact, an unbalanced force is developed at the interface stretched over the entire fluid mass. The intensity of molecular attraction per unit length along any line in the surface is called as surface tension.

8 b) **5M**

▶ 5.6 CONTINUITY EQUATION IN THREE-DIMENSIONS

Consider a fluid element of lengths dx, dy and dz in the direction of x, y and z. Let u, v and w are the inlet velocity components in x, y and z directions respectively. Mass of fluid entering the face $ABCD$ per second

$$= \rho \times \text{Velocity in } x\text{-direction} \times \text{Area of } ABCD$$
$$= \rho \times u \times (dy \times dz)$$

Then mass of fluid leaving the face $EFGH$ per second $= \rho u \, dydz + \dfrac{\partial}{\partial x}(\rho u \, dydz)\, dx$

∴ Gain of mass in x-direction

$$= \text{Mass through } ABCD - \text{Mass through } EFGH \text{ per second}$$
$$= \rho u \, dydz - \rho u \, dydz - \frac{\partial}{\partial x}(\rho u \, dydz) dx$$
$$= -\frac{\partial}{\partial x}(\rho u \, dydz)\, dx$$
$$= -\frac{\partial}{\partial x}(\rho u)\, dx \, dydz \qquad \{\because dydz \text{ is constant}\}$$

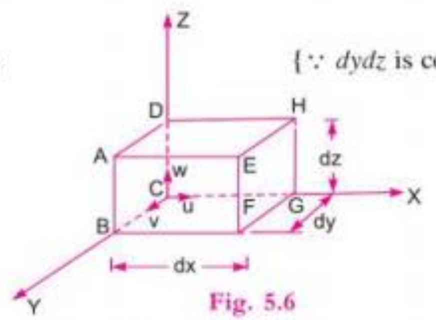

Fig. 5.6

Similarly, the net gain of mass in y-direction

$$= -\frac{\partial}{\partial y}(\rho v)\, dxdydz$$

and in z-direction

$$= -\frac{\partial}{\partial z}(\rho w)\, dxdydz$$

∴ Net gain of masses $= -\left[\dfrac{\partial}{\partial x}(\rho u) + \dfrac{\partial}{\partial y}(\rho v) + \dfrac{\partial}{\partial z}(\rho w)\right] dxdydz$

Since the mass is neither created nor destroyed in the fluid element, the net increase of mass per unit time in the fluid element must be equal to the rate of increase of mass of fluid in the element. But mass of fluid in the element is ρ. dx. dy. dz and its rate of increase with time is $\frac{\partial}{\partial t}$ (ρ dx. dy. dz) or

$\frac{\partial \rho}{\partial t} \cdot dx\, dy\, dz.$

Equating the two expressions,

or $$-\left[\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)\right] dxdydz = \frac{\partial \rho}{\partial t} \cdot dxdydz$$

or $$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w) = 0$$ [Cancelling $dx.dy.dz$ from both sides] ...(5.3A)

Equation (5.3A) is the continuity equation in cartesian co-ordinates in its most general form. This equation is applicable to :

(*i*) Steady and unsteady flow,
(*ii*) Uniform and non-uniform flow, and
(*iii*) Compressible and incompressible fluids.

For steady flow, $\frac{\partial \rho}{\partial t} = 0$ and hence equation (5.3A) becomes as

$$\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w) = 0 \qquad ...(5.3B)$$

If the fluid is incompressible, then ρ is constant and the above equation becomes as

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z} = 0 \qquad ...(5.4)$$

Equation (5.4) is the continuity equation in three-dimensions. For a two-dimensional flow, the component $w = 0$ and hence continuity equation becomes as

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 0. \qquad ...(5.5)$$

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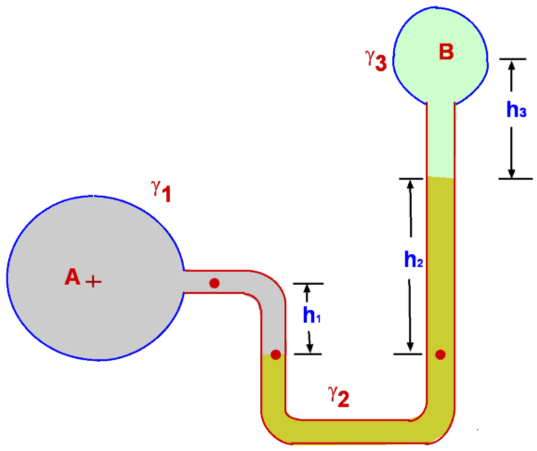
9 a) **5M**

Pressure is defined as a force per unit area - and the most accurate way to measure low air pressure is to balance a column of liquid of known weight against it and measure the height of the liquid column so balanced. The units of measure commonly used are inches of mercury (in. Hg), using mercury as the fluid and inches of water (in. w.c.), using water or oil as the fluid.

u-tube differential manometer is a **simple** differential u-tube manometer ZAR used to find the large. pressure differences and whereas inverted differential u2 matter meters are used to find the small pressures differences okay. so based upon the high and low pressure values



Differential U-tube manometer (Fig. 2.12) is very handy to measure the pressure difference directly and is basically similar to the U-tube manometer discussed above. What was the open end before is now connected to a different pressure, p_B so that we measure the difference

$p_A - p_B$

$p_A + \gamma_1 h_1 - \gamma_2 h_2 - \gamma_3 h_3 = p_B$

$p_A - p_B = \gamma_2 h_2 + \gamma_3 h_3 - \gamma_1 h_1$

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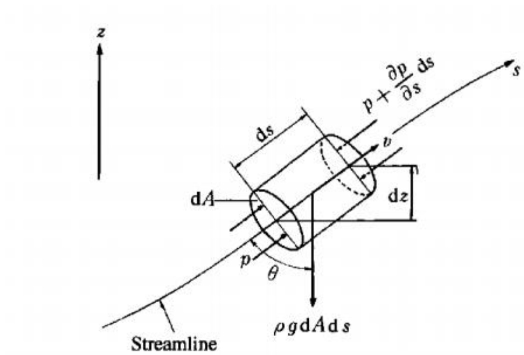
9 b) **5M**

A streamline (a line which follows the direction of the fluid velocity) is chosen with the coordinates shown in Fig. 5.4. Around this line, a cylindrical element of fluid having the cross-sectional area dA and length ds is considered. Let p be the pressure acting on the lower face, and pressure $p + (\partial p/\partial s)ds$ acts on the upper face a distance ds away. The gravitational force acting on this element is its weight, ρg dA ds. Applying Newton's second



.4 Force acting on fluid on streamline

law of motion to this element, the resultant force acting on it, and producing acceleration along the streamline, is the force due to the pressure difference across the streamline and the component of any other external force (in this case only the gravitational force) along the streamline.

Therefore the following equation is obtained:

$$\rho \, \mathrm{d}A \, \mathrm{d}s \frac{\mathrm{d}v}{\mathrm{d}t} = -\mathrm{d}A \frac{\partial p}{\partial s} \mathrm{d}s - \rho g \, \mathrm{d}A \, \mathrm{d}s \cos \theta$$

or

$$\frac{\mathrm{d}v}{\mathrm{d}t} = -\frac{1}{\rho} \frac{\partial p}{\partial s} - g \cos \theta \tag{5.3}$$

The velocity may change with both position and time. In one-dimensional flow it therefore becomes a function of distance and time, $v = v(s, t)$. The change in velocity $\mathrm{d}v$ over time $\mathrm{d}t$ may be written as

$$\mathrm{d}v = \frac{\partial v}{\partial t} \mathrm{d}t + \frac{\partial v}{\partial s} \mathrm{d}s$$

The acceleration is then

$$\frac{\mathrm{d}v}{\mathrm{d}t} = \frac{\partial v}{\partial t} + \frac{\partial v}{\partial t} \frac{\mathrm{d}s}{\mathrm{d}t} = \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial s}$$

If the z axis is the vertical direction as shown in Fig. 5.4, then

$$\cos \theta = \mathrm{d}z/\mathrm{d}s$$

So eqn (5.3) becomes

$$\frac{\partial v}{\partial t} + v \frac{\partial v}{\partial s} = -\frac{1}{\rho} \frac{\partial p}{\partial s} - g \frac{\mathrm{d}z}{\mathrm{d}s} \tag{5.4}$$

In the steady state, $\partial v/\partial t = 0$ and eqn (5.4) would then become

$$v\frac{dv}{ds} = -\frac{1}{\rho}\frac{dp}{ds} - g\frac{dz}{ds} \tag{5.5}$$

Equation (5.4) or (5.5) is called Euler's equation of motion for one-dimensional non-viscous fluid flow. In incompressible fluid flow with two unknowns (v and p), the continuity equation (5.2) must be solved simultaneously. In compressible flow, ρ becomes unknown, too. So by adding a third equation of state for a perfect gas (2.14), a solution can be obtained.

Equation (5.5) is integrated with respect to s to obtain a relationship between points a finite distance apart along the streamline. This gives

$$\frac{v^2}{2} + \int\frac{dp}{\rho} + gz = \text{constant} \tag{5.6}$$

and for an incompressible fluid (ρ = constant),

$$\frac{v^2}{2} + \frac{p}{\rho} + gz = \text{constant} \tag{5.7}$$

between arbitrary points, and therefore at all points, along a streamline.

Dividing each term in eqn (5.7) by g,

$$\frac{v^2}{2g} + \frac{p}{\rho g} + z = H = \text{constant} \tag{5.8}$$

Multiplying each term of eqn (5.7) by ρ,

$$\frac{\rho v^2}{2} + p + \rho gz = \text{constant} \tag{5.9}$$

(5.7) represent the kinetic energy, energy due to pressure and potential energy respectively, per unit mass.

The terms of eqn (5.8) represent energy per unit weight, and they have the units of length (m) so they are commonly termed heads.

$\frac{v^2}{2g}$: velocity head

$\frac{p}{\rho g}$: pressure head

z: potential head

H: total head

Then from Bernoulli's equation

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$