Technocrats Institute of Technology, Bhopal

Subject: Basic Mechanical Engineering (BT-203)

Submitted By: Prof. Kuldeep Singh Parihar

UNIT – 1

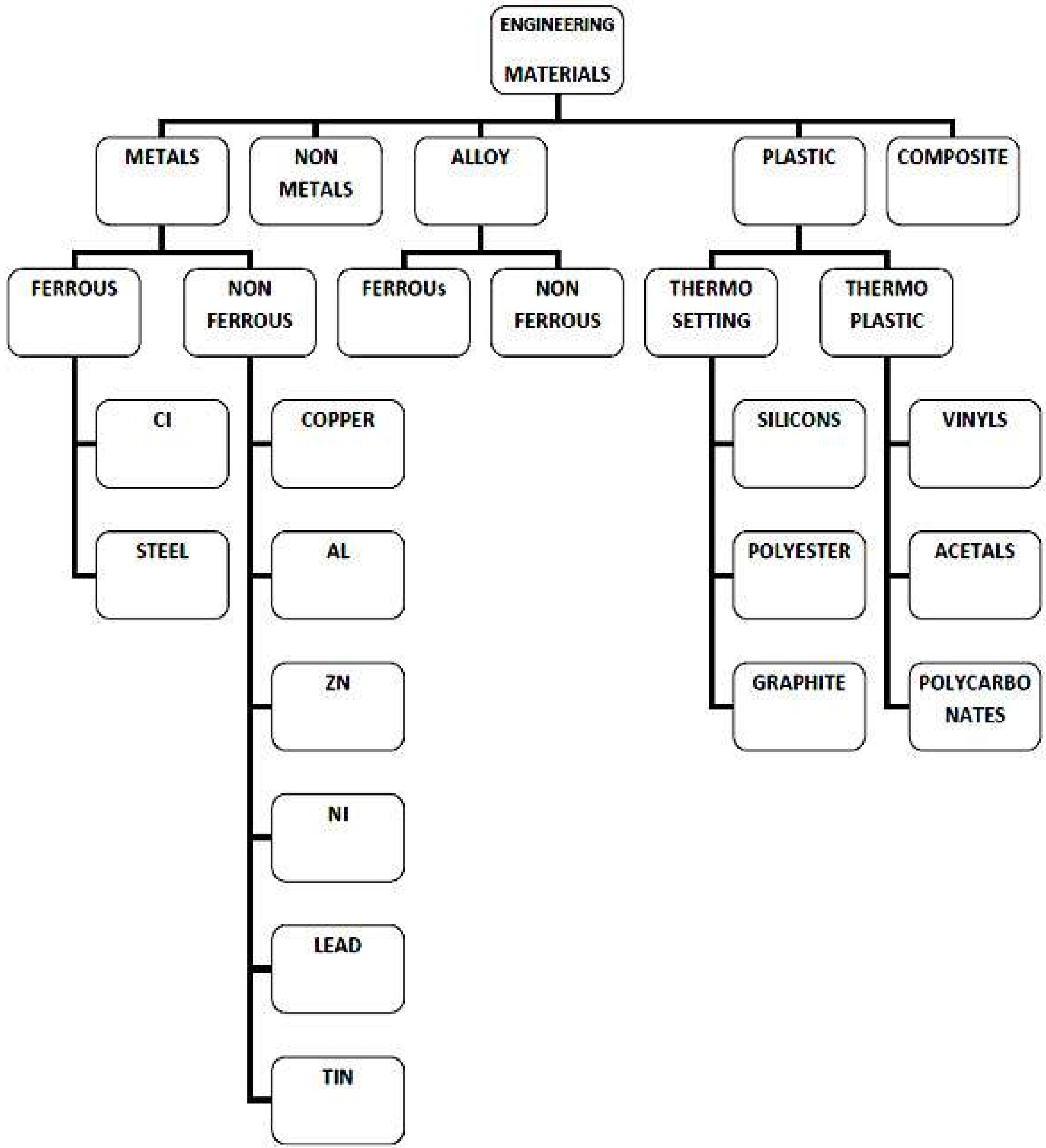
Introduction and classification of materials

Unit-01/Lecture-01

Introduction

A material is a thing which can make anything or by the help of materials we can process any component of our requirement. Various types of materials are available but all material are not considered as engineering materials, Because engineering materials are those materials which are use for synthesis of engineering component as like crank ,piston cylinder ,crank shaft, machine structures etc.

Classification of materials.[RGPV June- 09 (20,10,marks) June 12, 14 (10,3 marks)]



How the engineering materials differ from other materials **[RGPV - Dec. 05(5 marks)]**

The main engineering requirements of materials which make the differ from other materials are follows—

Fabrication requirements: - Two basic Fabrication requirements of engineering materials are that it should be able to get shaped and joined with other materials.

Service requirements:-the material selected for the purpose must stand up to service requirement. It should have an adequate dimensional stability, corrosion requirement strength toughness hardness, heat resistance, low electrical resistance etc.

Economic requirements: - economic requirement demand that the engineering part should be made with minimum overall cost.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	How do engineering materials differ from other materials?	Dec2005	5
Q.2	How the engineering materials are classified? Give their classification.	June2009	20
Q.3	Write in detail about the classification of materials.	Dec2009	10
Q.3	Give the classification of carbon steel.	June2014	3
Q.5	How do you classify engineering materials? List different types of engineering materials along with their uses.	June 2012 (Non grading)	10

Unit-01/Lecture-02

Properties of engineering materials **[RGPV feb.06(14 marks) June 05,08(8,10 marks)June 11,13,(7 marks)]**

(1) Physical properties

(2) Chemical properties

(3) Dimensional properties

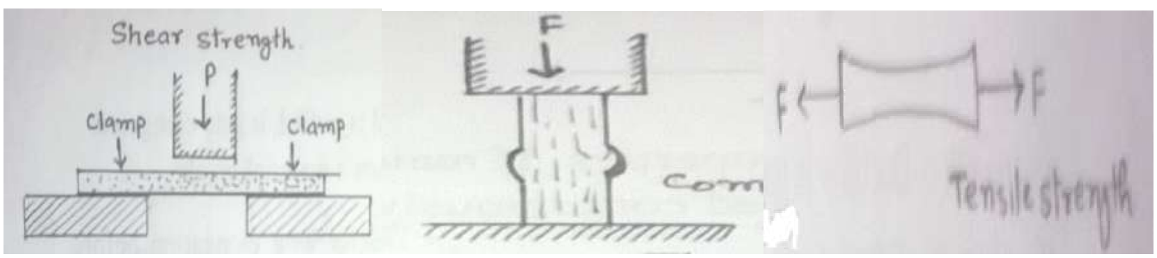
(4) Manufacturing properties

Machinability , castability, weldability

(5) Mechanical properties

(1) Strength (2) Elasticity
(3) Plasticity (4) Ductility
(5) Hardness (5) Malleability
(6)Hardness (7) Creep
(8)Fatigue (9) Toughness
(10)Brittleness

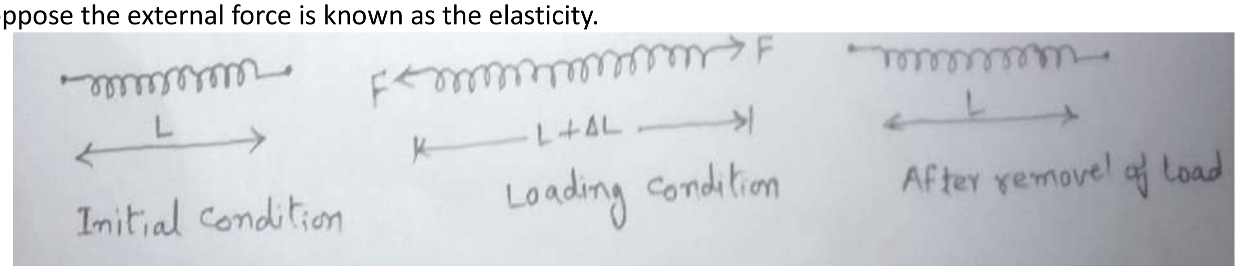
(1) Strength: - it is the ability of material to withstand the external force without destruction or breaking. A stronger material can withstand greater load.



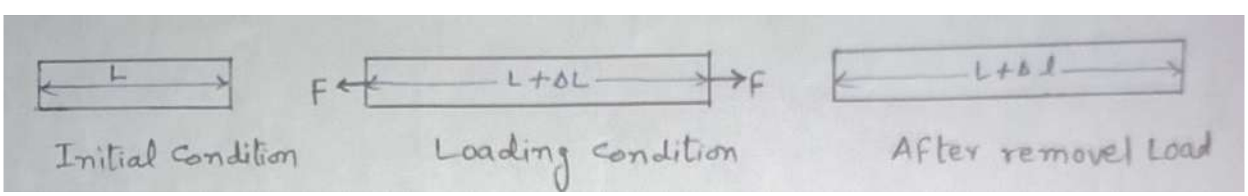
Shear strength compressive strength tensile strength

The strength of materials varies according to the type of loading i.e., tensile strength, compressive strength.

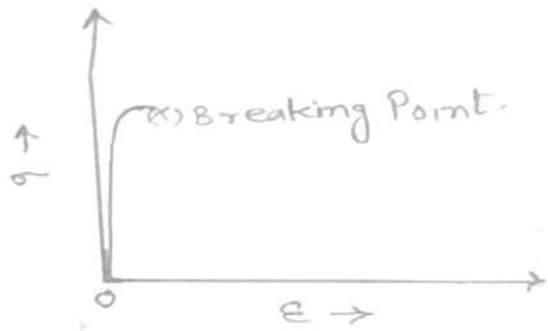
(2)Elasticity: - When a material is subjected to load, it undergoes deformation, during deformation internal forces are generated between the molecules, which oppose the external force. This properties of material oppose the external force is known as the elasticity.



(3) Plasticity: - When a material is subjected to a load, then it undergoes permanent deformation. This properties of material undergoes permanent deformation is known plasticity.



(4)Brittleness: - When load is subjected to brittle material, then brittle material dose not deform much when loaded or very minor deformation take place. It simply breaks when subjected load reach certain limit. Brittle materials are weak in tension but strong in compression.



Difference between Ductility and Malleability [Rgpv June 2014]

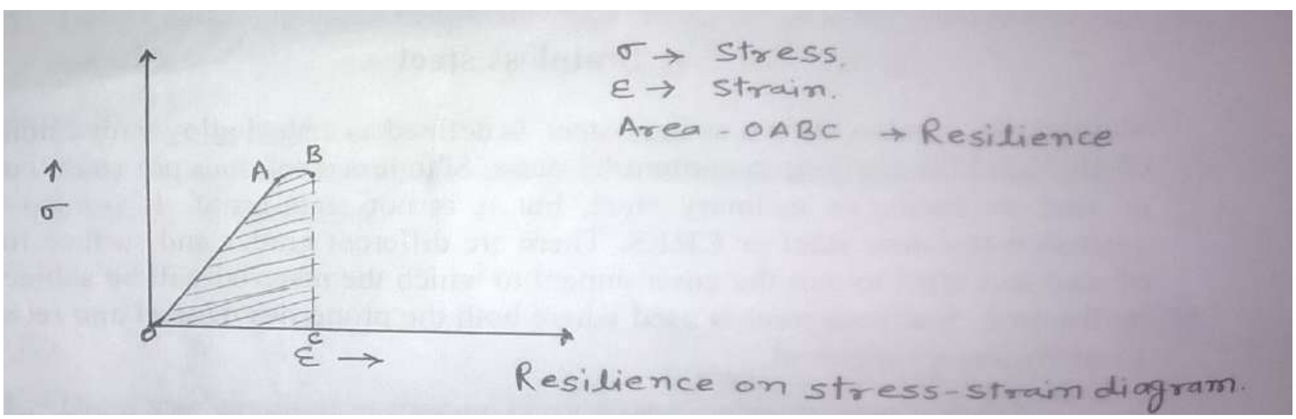
(5)Ductility:-Ductility is tensile properties. If material is pulled, it gets elongated. If magnitude of the force is increased continuously, then a material breaks. A material which undergoes for long elongation before breaking is called ductile material and this property is called ductility.

(6)Malleability: - Malleability is compressive properties material is called malleable if it can be hammered to make thin sheet. Lead and Al have high malleability.

(7)Resilience: - [Rgpv- June 10 (2) marks]

This property of engineering material to absorb energy before undergoing plastic deformation. This phenomenon is known resilience.

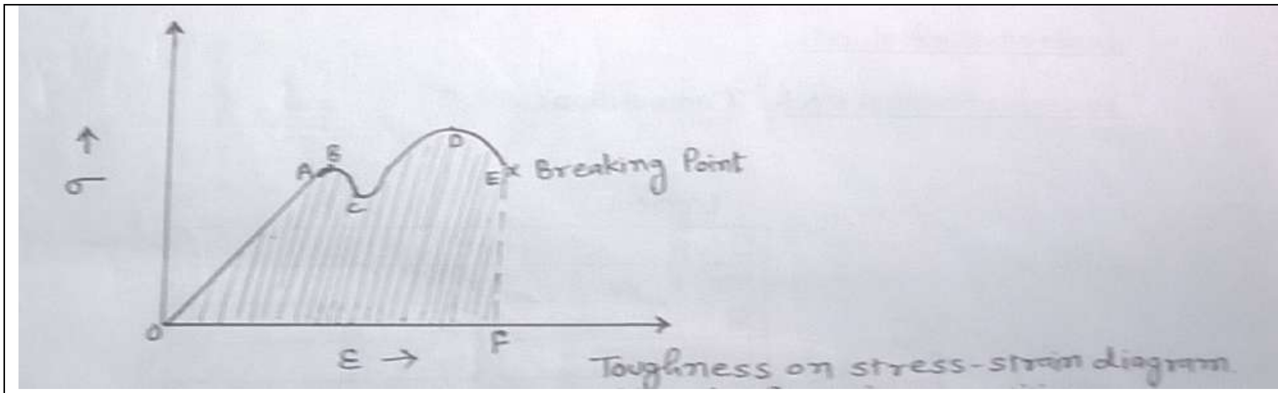
The strain energy stored in the body due to external loading within elastic limit is known as resilience, and maximum energy which can be stored in a body up to elastic limit is called proof resilience.



(7)Creep: - [Rgpv- June 10 (2) marks]

When a material is subject for long time period at constant load, then material start slow and permanent deformation called creep.

(8)Toughness:-When a material is subjected to load, it undergoes deformation. Toughness (tenacity) is the strength with which the material opposes rupture. It is due to the attraction which the molecules have for each other giving them power to resist tearing apart.



(9) Fatigue: - When a machine component subjected to fluctuating or repetitive or variable loading, it fails even when the applied load is very high. Such failure takes places due to fatigue.

(10) Hardness: - hardness may be defined as properties of engg. Materials which resists scratching, wear, abrasion, cutting abrasion, cutting, machining indention. High carbon steel, high speed steel and steel alloyed with titanium have high hardness.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Define tensile strength of materials.	Jan 2015	2
Q.2	Describe the mechanical properties of engineering.	Feb.2006	14
Q.3	Write a short note on – Mechanical properties of materials.	June.2005	8
Q.4	Write about the various mechanical properties of metals	June.2008	10
Q.5	Define the following properties of engg. Materials: Proportionally limit, resilience, creep brittleness, wear	June.2010	10
Q. 6	Define the following mechanical properties of engineering materials: Ductility, brittleness, toughness	Dec.2011	6
Q.6	explain the difference between Malleability and ductility	June 2014	2
Q.7	Define following properties of engineering materials : i) Hardness ii) Ductility iii) Fatigue iv) Modulus of elasticity	June 2013	7
Q.8	Define the following mechanical properties of engineering materials: Ductility, hardness, toughness, machinability	June 2012	7
Q.9	Describe the various mechanical properties of materials in short.	June 2011	7

Unit-01/Lecture-03

Steel- [**RGPV June 02,April 09,11 Dec 03, 07, 08]**

The term steel is used for many different alloys of iron. These alloys vary both in the way they are made and in the proportions of the materials added to the iron. All steels, however, contain small amounts of carbon and manganese. In other words, it can be said that steel is a crystalline alloy of iron, carbon and several other elements, which hardens above its critical temperature. Like stated above, there do exist several types of steels which are (among others) plain carbon, stainless steel, alloyed steel and tool steel.

Plain carbon steel.

Carbon steel is by far the most widely used kind of steel. The properties of carbon steel depend primarily on the amount of carbon it contains. Most carbon steel has a carbon content of less than 1%. Carbon steel is made into a wide range of products, including structural beams, car bodies, kitchen appliances, and cans. In fact, there are 3 types of plain carbon steel and they are low carbon steel, medium carbon steel, high carbon steel, and as their names suggests all these types of plain carbon steel differs in the amount of carbon they contain. Indeed, it is good to precise that plain carbon steel is a type of steel having a maximum carbon content of 1.5% along with small percentages of silica, sulphur, phosphorus and manganese.

Types of Plain carbon steel.

Low carbon steel or mild steel, containing carbon up to 0.25% responds to heat treatment as improvement in the ductility is concerned but has no effect in respect of its strength properties.

Medium carbon steels, having carbon content ranging from 0.25 to 0.70% improves in the machinability by heat treatment. It must also be noted that this steel is especially adaptable for machining or forging and where surface hardness is desirable.

High carbon steels, is steel-containing carbon in the range of 0.70 to 1.05% and is especially classed as high carbon steel. In the fully heat-treated condition it is very hard and it will withstand high shear and wear and will thus be subjected to little deformation.

Stainless steel

Stainless steel – Stainless steel, also known as inox steel, is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass. Stainless steel does not stain, corrode, or rust as easily as ordinary steel, but it is not stain-proof. It is also called corrosion-resistant steel or **CRES**. There are different grades and surface finishes of stainless steel to suit the environment to which the material will be subjected in its lifetime. Stainless steel is used where both the properties of steel and resistance to corrosion are required.

Stainless steel differs from carbon steel by the amount of chromium present. Carbon steel rusts when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide. Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure.

Types of stainless steels

Austenitic Stainless steel- (Composition)

Element	%
C	0.05 to 0.15
Mn	2 to 10
Si	1 to2
Cr	16 to 26
Ni	8 to 22

Properties

1. These steel possess austenitic structure at room temp. because of containing Ni
2. These steels possess greatest strength and scale resistance at high temp.
3. These steel are non magnetic and possess greatest resistance to corrosion and good mechanical properties at elevated temp.
4. These steels can be easily welded.
5. These steel are very tough and can be forged and rolled offer great difficulty in machining.

Uses

1. These steel are used in chemical processing, paper making and dairy industries.
2. Used in engine parts of aircrafts, trailers and railway cars etc.

Martenstic stainless steel- (composition)

Element	%
C	0.03 to 0.25
Mn	2 to 10
Si	1 to2
Cr	16 to 26
Ni	3.5 to 22

Properties-

1. These steel are magnetic in all condition and possess the best thermal conductivity of stainless type.
2. These steel can be easily welded and machined.
3. These steels can be cold worked without difficulty.
4. These steels have good toughness and good corrosion resistance to weather.

Uses

These are used for cutlery, spring, and surgical, dental instrument.

Ferritic stainless steels- **(Composition)**

Element	%
C	0.08 to 0.20
Mn	1 to 1.5
Si	1
Cr	11 to 28

Properties-

1. These steel are magnetic and have good ductility.
2. These steel are more corrosion resistance than martensitic steels.
3. These steels have lower strength elevated martensitic steels.
4. These steels develop their maximum softness, ductility, and corrosion resistance in annealed condition.

Uses-

These steels are mainly used as sheet for cold forming and pressing operation for the purpose where moderate corrosion resistance is required.
These steels are widely used for pump shaft, spindles and valves.

Alloying element **[RGPV June08, 10,]**

Effect of alloying element and impurities in cast iron and steel

Carbon

Normally 2 to 4% carbon is present in cast iron. The carbon presents in cast iron either as cementite (Fe3c), a very hard constituent or graphite a soft element. The percentage presence of cementite makes the cast iron brittle and hard, while presence of graphite makes the cast iron tougher and ductile.

Silicon

Its presence in the cast iron increases grayness and fluidity and ensures softer and better castings and it may be present up to 3%.

Phosphorus

It is present in cast iron up to 0.3%. Its presence in the cast iron lower the melting point, increases fluidity, reduces shrinkage in castings. It also increases the strength of cast iron.

Sulphur

It is present in cast iron up to 0.15%.It has hardening effect in cast iron.

Manganese

It is present in cost iron up to 1%. It increases the hardness and tensile strength of cast iron.

Nickel

When nickel is added to cast iron, it promotes the graphite formation. It increases hardness, strength, machinability and corrosion resistance.

Chromium

It is present in cast iron upto3%. Its presence with cast iron promotes the formation of carbide (cementite), a hard element of carbon. It increases wear resistance, hardness, strength, but reduces ductility.

Molybdenum

Its small presence in cast iron improves strength and wear resistance. But its large presence increases hardness and reduces the machinability.

Vanadium

It is present in cast iron up to 0.5%. It promotes carbide formation, thus increases the hardness and strength of cast iron.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Give the composition and properties of high carbon steel and high speed steel.	June 2002	8
Q.2	Give the composition and properties and uses of high carbon steel and high speed steel.	Dec 2003, Dec 2007	8,10
Q.3	Discuss the composition , specific properties and main application of the following materials (i)Mild steel, (ii) High carbon steel (iii) High carbon steel (iv) stainless steel.	April 2009	5 each
Q.4	Explain the properties and uses of stainless steel.	Dec 2008	10
Q.5	Define steel .discuss its various types, uses and their application.	June 2011	7
Q.6	Discuss the effect of the following alloying element in steel-Chromium, Nickel, Tungsten, Sulphur.	June 2008	10
Q.7	What are alloy steel? Why alloying is done. Explain	June 2013	7
Q.8	What is alloy steel? Name two type of alloy steel giving their composition and uses.		
Q.9	Discuss the effect of the alloying element on the properties of cast iron.	June 2011	7

Unit-01/Lecture-04

Cast iron-[RGPV June 04,07,08,11 Dec 01, 07, 08, 11]

Cast iron- Cast iron: - Basically it is alloys of iron and carbon, containing up to 2.14% carbon are called steel, and these alloys containing carbon above 2.14% are called cast iron.

It is obtained by melting the pig iron with coke and lime stone in furnace. Carbon in the cast iron usually exists in two forms-

(1) Graphite

(2) Carbide

Composition:-

C	Si	S	P	Mn	Fe
2.14-6.67	**0.5-1.0**	**0.06-0.12**	**0.10-0.30**	**0.10-1.0**	**Balance**

PROPERTIES:-

1. Low tensile strength, but high compressive strength
2. Good hardness and wear resistance.
3. Good castability.
4. Very low ductility.

Uses:-

Machine structure, frame for electric motors, cylinder block cylinder head

Types of cast iron:-

(1) Grey cast iron
(2) White cast iron
(3) Malleable cast iron
(4) Ductile cast iron

Grey cast iron: - if iron containing carbon in the form of graphite and this graphite are softer and easily machinable known as grey cast iron. Grey cast iron is obtained by allowing the molten metal to cool and solidify slowly.

Composition:-

C	Si	S	P	Mn	Fe
2.5-3.75	**1.0-2.75**	**.06-0.12**	**0.10-1.0**	**0.4-1.0**	**Balance**

Properties:-

(1) Low tensile strength

(2) It has high resistance to wear

(3) It has good machinability

(4) Grey cast iron has high fluidity

(5) Good castability

Uses: - Machine frame, automobile cylinder block gears, fly ball etc.

White cast iron: - If iron containing carbon in the form of carbide, which is hard and difficult to

Machine is known as white cast iron It is obtained by rapid cooling.

Composition:-

C	Si	S	P	Mn	Fe
1.75-2.30	**0.85-1.20**	**0.12-0.35**	**.005-0.20**	**0.10-1.20**	**Balance**

Properties:-

(1) It is very hard and brittle.

(2) Good wear resistance properties.

(3) Unmachinable.

(4) Solidification range of white cast iron is 2250- 2065f.

Uses: - It is use for making wrought iron, roller of rolling mills, rail road wheel, grinding wheel, agriculture application etc.

Malleable cast iron:-Malleable cast iron is obtained from white cast iron by suitable heat treatment process. Due to hardness and brittleness of grey cast iron and white cast iron is not suitable for making the component subjected to shock and impact load, for such application malleable cast iron.

Composition:-

C	Si	S	P	Mn	Fe
2.20-3.60	**0.40-1.10**	**0.03-0.40**	**0.10-0.20**	**0.10-0.40**	**Balance**

Properties:-

(1) It has very good machinability and weldability.

(2) It has low thermal expansion.

(3) It has good wear resistance and vibration damping.

Uses: - for making gear, casing, automotive crank shaft, universal joint etc.

Ductile cast iron

Composition:-

C	Si	P	Mn	Fe
3.2-3.4	**1.1-3.5**	**0.08-0.1**	**0.03-0.07**	**Balance**

Properties:-

(1) Good wear resistance.

(2) Good damping capacity.

(3) It has good castability

(4) High fluidity

Uses: - it is use for making the crank shaft, cylinder head, press work equipment, IC engine parts, construction machinery gears etc.
The analysis of coal in which % of C , H ,N ,S and O elements are

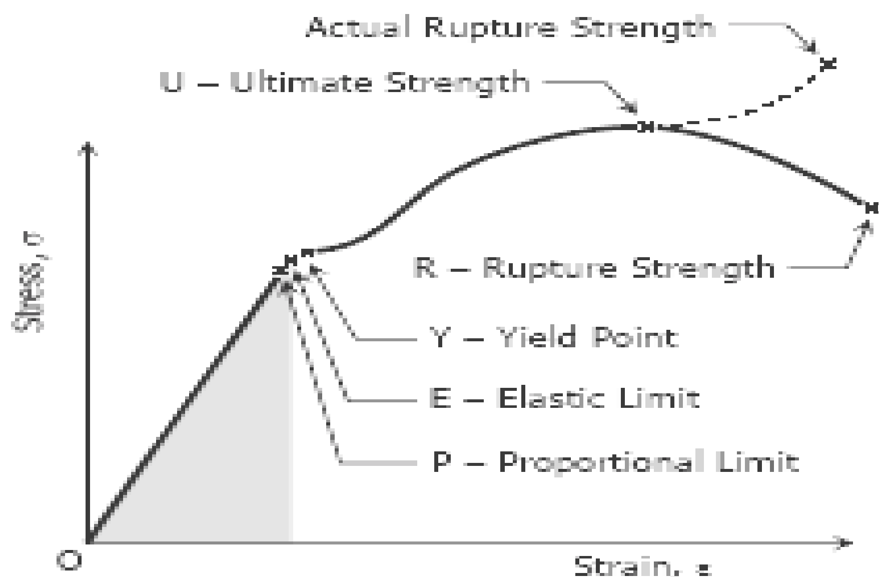
S.NO	RGPV QUESTIONS	Year	Marks
Q.1	State the composition of grey cast iron and its application.	Jan 2015	2015
Q.2	Write down the composition of cast iron, carbon steel and few alloy steels and enlist engineering application of these materials.	Sept.2009	20
Q.3	Write classification and properties of cast iron.	Dec.2008	10
Q.4	Give in brief the composition, properties and uses of cast iron.	Dec.2007	10
Q.5	Give applications of cast iron and carbon. Give classification of engineering materials on steels (at least - 5) plot stress strain curve for Cast iron. Distinguish between stress-strain cuve and true stress-strain curve.	Dec 2013	14
Q.6	Give in brief the composition, properties and uses of cast iron	Dec.2001, June 2004	10,10
Q.7	Write a short note on – cast iron.	Jan.2008	10
Q.8	Describe composition of grey cast iron and its properties and application in engineering Field	June 2013	7
Q.9	What is cast iron? What are different types of cast iron? Discuss their properties.	Dec 2011	8

UNIT 1/LECTURE 5

stress-strain diagram [RGPV -June 09,08, 10, 11 Dec 02, , 08, 10]
Stress-strain diagram for mild steel

Suppose that a metal specimen be placed in tension-compression testing machine. As the axial load is gradually increased in increments, the total elongation over the gage length is measured at each increment of the load and this is continued until failure of the specimen takes place. Knowing the original cross-sectional area and length of the specimen, the normal stress σ and the strain ε can be obtained. The graph of these quantities with the stress σ along the y-axis and the strain ε along the x-axis is called the stress-strain diagram. The stress-strain diagram differs in form for various materials. The diagram shown below is that for a medium carbon structural steel.

Metallic engineering materials are classified as either ductile or brittle materials. A ductile material is one having relatively large tensile strains up to the point of rupture like structural steel and aluminum, whereas brittle materials has a relatively small strain up to the point of rupture like cast iron and concrete. An arbitrary strain of 0.05 mm/mm is frequently taken as the dividing line between these two classes.



Proportional limit (Hooke's law)

From the origin O to the point called proportional limit, the stress-strain curve is a straight line. This linear relation between elongation and the axial force causing was first noticed by Sir Robert Hooke in 1678 and is called Hooke's Law that within the proportional limit, the stress is directly proportional to strain or

$$\sigma \alpha \varepsilon \quad \text{OR} \quad \sigma = k\,\varepsilon$$

The constant of proportionality k is called the Modulus of Elasticity E or Young's Modulus and is equal to the slope of the stress-strain diagram from O to P. Then

Elastic Limit

The elastic limit is the limit beyond which the material will no longer go back to its original shape when the load is removed, or it is the maximum stress that may e developed such that there is no permanent or residual deformation when the load is entirely removed.

Elastic And Plastic Ranges

The region in stress-strain diagram from O to P is called the elastic range. The region from P to R is called the plastic range.

Yield Point Yield point is the point at which the material will have an appreciable elongation or yielding without any increase in load.

Ultimate Strength The maximum ordinate in the stress-strain diagram is the ultimate strength or tensile strength.

Rapture Strength Rapture strength is the strength of the material at rupture. This is also known as the breaking strength.

S.NO	RGPV QUESTION	YEAR	MARKS
Q.1	What is modulus of elasticity? Give its unit of measurement.	Jan 2015	3
Q.2	Draw the stress-strain diagram for ductile and brittle materials and discuss it showing all important point.	DEC 2002	10
Q.3	Draw and explain stress-strain curve for an elastic materials.	DEC 2008	10
Q.4	Draw a nominated stress- strain diagram for ductile material like mild steel and write down Hook's law.	June 2009	20
Q.5	Explain the stress-strain diagram of mild steel and cast iron with neat sketches.	June 2008	10
Q.6	Explain the stress strain diagram for mild steel.	June 2014	2
Q.7	Explain the stress-strain diagram of mild steel with the help of a neat sketch.	Jun 2013	7
Q.8	A rod 150 cm long and diameter 2 cm is subjected to an axial pull of 20 kN. If the modulus of elasticity of the material of the rod is 2 × 105 N/mm2, determine stress, Strain, and the elongation of the rod.	June2014	7
Q.9	Discuss the stress strain curve for ductile materials.	June 2012	7
Q.10	Sketch stress strain diagram for M.S. and cast iron. Discuss various point for M.S.	June 2011	7
Q.11	Define the Hooks law and modulus of elasticity.	June 2012 (Non grading)	10

UNIT 1/LECTURE 6

Iron carbon equilibrium diagram [RGPV/ Dec 08, 11]

- Iron carbon diagram indicates the phase changes that occur during heating or cooling.
- Iron carbon diagram establish the relation between the microstructure and properties of steel.

Allotropic

Iron, when cooling from a high temperature, displays two special points known as arrest points or critical points. These change points occur at 1390^{0}C and 910^{0}C. Above 1390^{0}C Iron exists with a BCC lattice but between 1390^{0}C and 910^{0}Cit exists with a FCC lattice. Iron is said to be allotropic, which means that it can exist in two different forms depending on temperature.

Eutectic Point

- At this special change point, the liquid steel changes to the solid austenite + cementite phase without going through the pasty stage.
- This occurs at 1140^{0}C for steel when 4.3% carbon is contained in the alloy.

Eutectoid Point

- At this special change point the solid austenite changes into solid pearlite.
- This occurs at 723^{0}C for steel when 0.83 % carbon is contained in the alloy.
- Eutectoid – solid.

Ferrite

- This is almost pure iron but contains about 0.02% carbon.
- It has a BCC structure.

Cementite

- This is a compound of iron and carbon.
- It is called Iron Carbide (Fe3C). It is a hard, brittle material.
- This is what gives the hardness to high carbon steel.
- It has a higher melting point than either of its elements

Pearlite

- At them eutectoid point (0.83% carbon) solid austenite changes into two solid phases - ferrite and cementite.
- These two solids combine to form pearlite.
- Pearlite is a layered structure of ferrite and cementoide.

Austenite

- This is an FCC solid solution structure which can contain up to 2% carbon.
- It is a hard non-magnetic substance.

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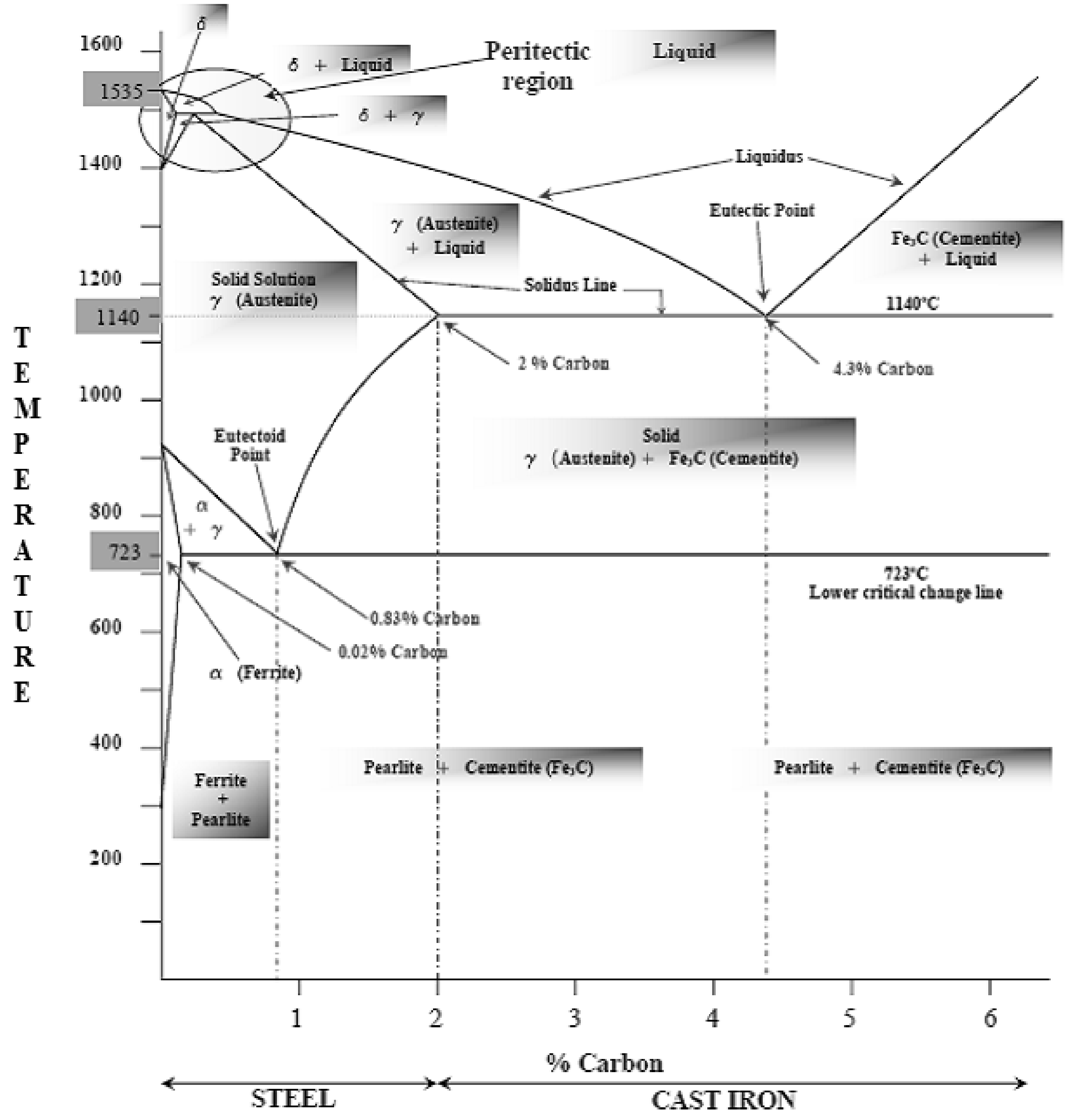


S.NO	RGPV QUESTION	YEAR	MARKS
Q.1	Explain the iron carbon diagram.	Jan 2015	7
Q.2	Draw a neat sketch of iron- carbon equilibrium diagram and explain the following reaction- Eutectic reaction, Eutectoide reaction, Peritectic reaction	Jan,feb 2008	10
Q.3	Draw and explain iron carbon equilibrium diagram.	Dec.2011	7
Q.4	Explain the Steel and Iron Carbon diagram.	June2014	7
Q.5	Discuss the iron carbon diagram and various allotropies of steel.	Dec 2011	8

UNIT 1/LECTURE 7

Testing of materials - [RGPV/ Dec 10, 11)]

Testing of materials

Materials are tested for one or more of the following purpose:

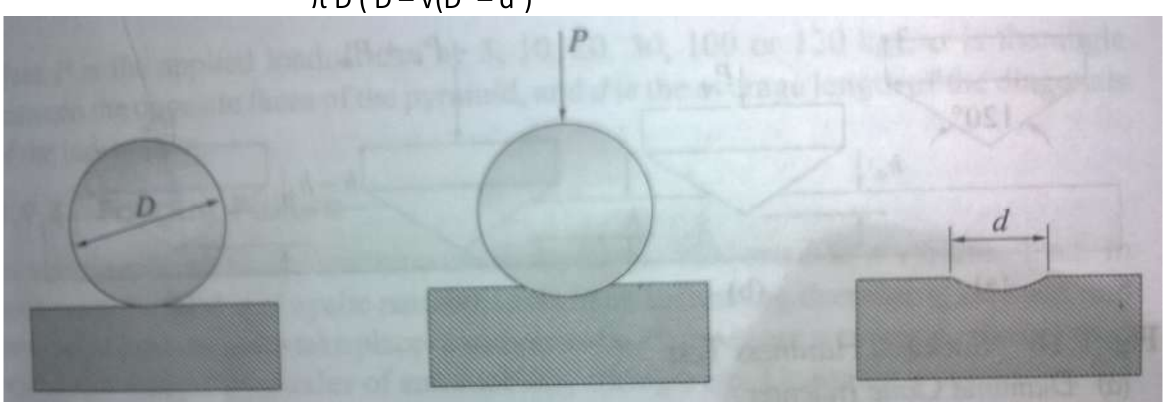
(1)To calculate numerically the fundamental mechanical properties of ductility, malleability, toughness etc.
(2) To check chemical composition.
(3)To determine suitability of a material for a particular use.
(4)To determine stress-strain values for design purpose.
(5)To determine surface defects of materials.

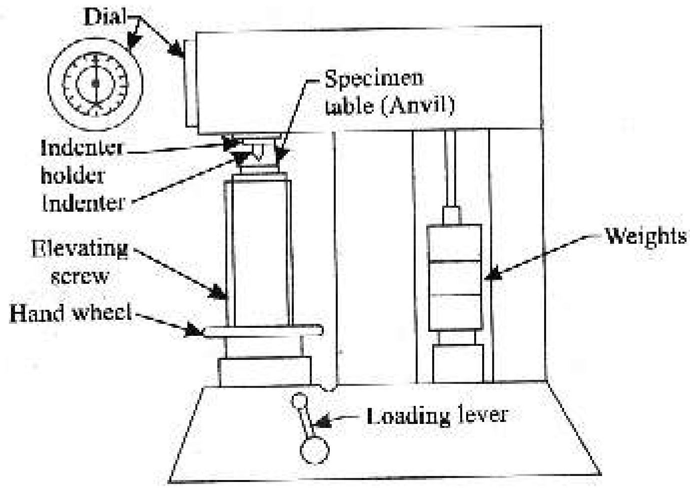
Classification:
(A) Non – destructive tests

(B) Destructive test

Non – destructive tests: In non – destructive testing, the component does not break and even can be used after testing.
Examples. Radiography, ultrasonic inspection etc.
Destructive test: In destructive testing, the component either breaks or remains no longer useful for further application. Destructive test are also known as mechanical test. Examples. Tensile test, impact test, hardness test etc.
Brinell Hardness Test
In this method, the indenter is a hard spherical ball, made of tungsten carbide. Diameter of this ball is generally 10 mm. this ball is pressed against the plane and polished surface of the materials. The applied load has a magnitude of 3000 kgf for steel and cast irons, 1000 kgf copper and its alloys, and 250 kgf for soft materials like aluminum, aluminum alloy, and babbit. The indenter creates a crater shaped impression on the materials. Geometrically this impression, or indentation, is a part of sphere .the diameter of indentation is measured. The value of hardness obtained by this method is denoted by Brinell Hardness Number. This number is determined by the formula,

$$BHN = \frac{2P}{\pi D \left(D - \sqrt{(D^2 - d^2}\right)}$$





Rockwell Hardness test
Theory: -
Hardness represents the resistance of material surface to abrasion, scratching and cutting, hardness after gives clear indication of strength. In all hardness tests, a define force is mechanically applied on the piece, varies in size and shape for different tests. Common indentors are made of hardened steel or diamond.

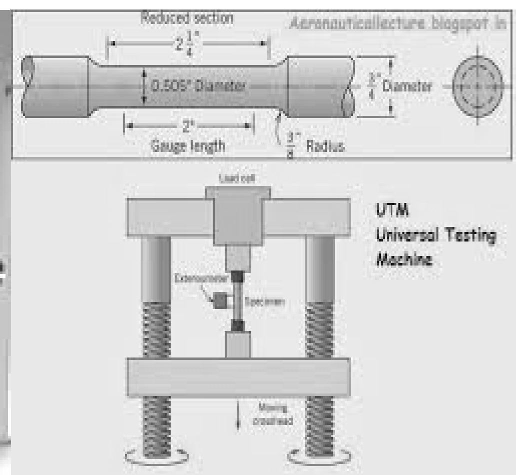
Rockwell hardness tester presents direct reading of hardness number on a dial provided with the m/c. principally this testing is similar to Brinell hardness testing.
It differs only in diameter and material of the indentor and the applied force. Although there are many scales having different combinations of load and size of
indentor but commonly 'C' scale is used and hardness is presented as HRC. Here the indentor has a diamond cone at the tip and applied force is of 150 kgf. Soft materials are often tested in 'B' scale with a 1.6mm dia. Steel indentor at 60kgf. A hardness test can be conducted can be conducted on Brinell testing m/c, Rockwell hardness m/c or vicker testing m/c. The specimen may be a cylinder, cube, thick or thin metallic sheet. A Brinell-cum-Rocwell hardness testing m/c along with the specimen is shown in figure.

Tensile Test
Theory:

Various m/c and structure components are subjected to tensile loading in numerous applications. For safe design of these components, their ultimate tensile strength and ductility one to be determine before actual use. Tensile test can be conducted on UTM. A material when subjected to a tensile load resists the applied load by developing internal resisting force. These resistances come due to atomic bonding
between atoms of the material. The resisting force for unit normal cross-section area is known as stress. The value of stress in material goes on increasing with an increase in applied tensile load, but it has a certain maximum (finite) limit too. The minimum stress, at which a material fails, is called ultimate tensile strength. The end of elastic limit is indicated by the yield point (load). This can be sen during experiment as explained later in procedure with increase in loading beyond elastic limit original cross-section area goes on decreasing and finally reduces to its minimum value when the specimen breaks.

About of UTM & its specifications:

The tensile test is conducted on UTM. It hydraulically operates a pump, oil in oil sump, load dial indicator and central buttons. The left has upper, middle and lower cross heads i.e; specimen grips (or jaws). Idle cross head can be moved up and down for adjustment. The pipes connecting the lift and right parts are oil pipes through which the pumped oil under pressure flows on left parts to more the crossheads

S.NO	RGPV QUESTION	YEAR	MARKS
Q.1	Define hardness and explain the Brinell hardness test	Jan 2015	7
Q.2	Define hardness. Explain any hardness testing method in brief.	Dec2011	6
Q.3	Explain the tensile testing of materials	Dec2010	7
Q.4	How does a stress-strain curve of a brittle material differ from a ductile material? Explain	Dec 2013	14

	with the help of a plot. On which machine the tensile test of a material is performed. What is the object of performing Fatigue test on a material?		
Q.5	Define hardness and explain the testing procedure for determining hardness of engineering materials.	June 2012	7

REFERENCCE

BOOK	AUTHOR	PRIORITY
Basic mechanical engineering	P.K. Nag	1
Basic mechanical engineering	D.K. Gupta	2

UNIT – 2 Unit-02

Measurement and machine tool

Unit-02/Lecture-01

Introduction & Definition

Definition of Measurement [RGPV June 11, 14 Dec 11]

Measurement is defined as the process of obtaining a quantitative comparison between a predefined standard & an unknown magnitude.

Example-consider the measurement of length of bar. We make use of a scale/steel ruler(i.e a standard)

Two basic methods are commonly employed for measurement.

Direct comparison

In this method, measurement is made directly by comparing the unknown magnitude with a standard & the result is expressed by a number. The simplest example for this would be, length measurement using a meter scale.

Drawbacks of Direct comparison methods

- The main drawback of this method is, the method is not always accurate and reliable.
- Also, human senses are not equipped to make direct comparison of all quantities with equal facility all the times.
- Also, measurement by direct methods is not always possible, feasible and practicable.

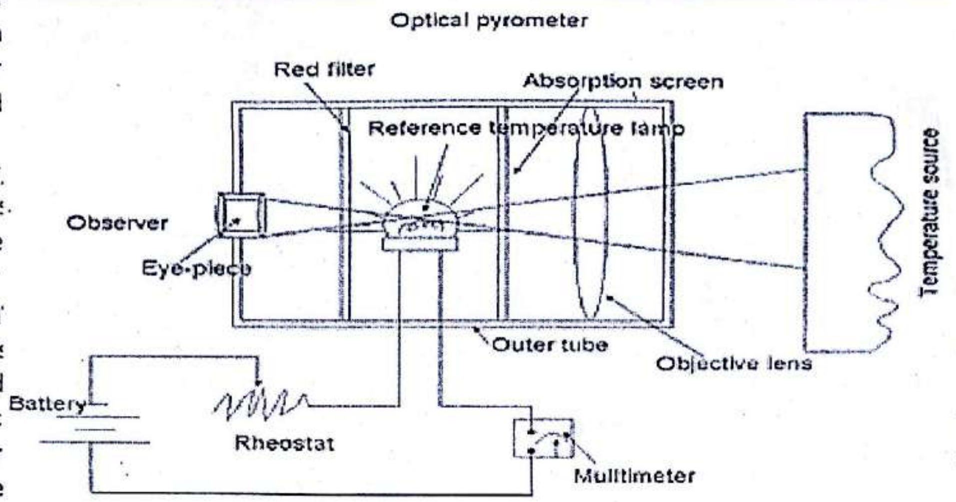
Example: Measurement of temperature, Measurement of weight.

- One can experience or feel the hotness or coldness of a body with respect to a particular environment. But may not be able to exactly predict or say the temperature. Further, these measurements in most cases involve human factors. Hence this method in general is not preferred and employed for very accurate measurements.

Indirect comparison

Most of the measurement systems use indirect method of measurement.

- In this method a chain of devices which is together called as *measuring system* is employed. The chain of devices transforms the sensed signal into a more convenient form & indicates this transformed signal either on an indicator or a recorder or fed to a controller i.e. it makes use of a transuding device/element which convert the basic form of input into an analogous form, which it then process



- For exa … ain, another compor … ssed suitably before l

Further … ain. But can feel or s … ire a system that de … cement of a pointer … uated stem.

DEFINI

1. **Meas** … vn standards be used
2. **Basic** … ance.
3. **Toler** … acceptable
4. **Dime**
5. **Dime** … n, etc.
6. **Limits** - These typically define a dimensional range that a measurement can be expected to fall within.
7. **Accuracy** - The expected ability for a system to discriminate between two settings. It is comparison of desired results with undesired results.
8. **Precision** - Implies a high degree of accuracy. It is the measure of the dispersion of the results.
9. **Repeatability** - Imperfections in mechanical systems can mean that during a Mechanical cycle, process does not stop at the same location, or move through the same spot each time. The variation range is referred to as repeatability.
10. **Standards** - a known set of dimensions, or ideals to compare others against.

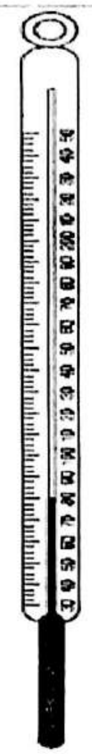
- Standards are the basis for all modern accuracy. As new methods are found to make more accurate standards, the level of accuracy possible in copies of the standard increase, and so on.
- A well known metric standard is the metric 1m rod.
- Many standards are available for measuring, and many techniques are available for comparison.

11. **Standard Sizes** - a component, or a dimension that is chosen from a table of standard sizes/forms.

Measurement of temperature

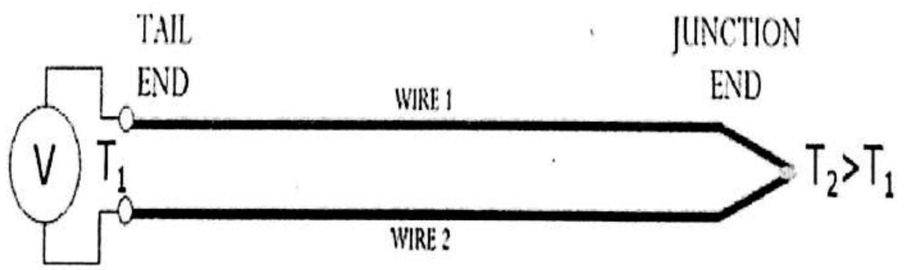
Mercury Thermometer

Mercury Thermometer consists of a bulb containing mercury attached to a glass tube of narrow diameter capillary. Volume of mercury in the tube is much less than the volume in the bulb. Volume of mercury changes slightly with temperature; A small change in volume drives the narrow mercury column a relatively long way up the tube. The space above the mercury may be filled with nitrogen or it may be at less than atmospheric pressure, a partial vacuum.



THERMOCOUPLES

Thermocouples are a device made by two different wires joined at one end, called junction end or measuring end. The two wires are called thermo elements or legs of the thermocouple. The other end of the thermocouple is called tail end or reference end. junction end is immersed in the environment whose temperature T_2 has to be measured, which can be for instance the temperature of a furnace at about 500°C, while the tail end is held at a different temperature T_1, e.g. at ambient temperature, Because of the temperature difference between junction end and tail end a voltage difference can be measured between the two thermo elements at the tail end: so the thermocouple is a temperature-voltage transducer.



THERMOCOUPLES

Optical pyrometer

Optical pyrometer compares the brightness of image produced by temperature source with that of reference temperature lamp. The current in the lamp is adjusted until the brightness of the lamp is equal to the brightness of the image produced by the temperature source. Since the Intensity of light of any wave length depends on the temperature of the radiating object the current passing through the lamp becomes a measure of the temperature of the temperature source when calibrated.

The main parts of an optical pyrometer:

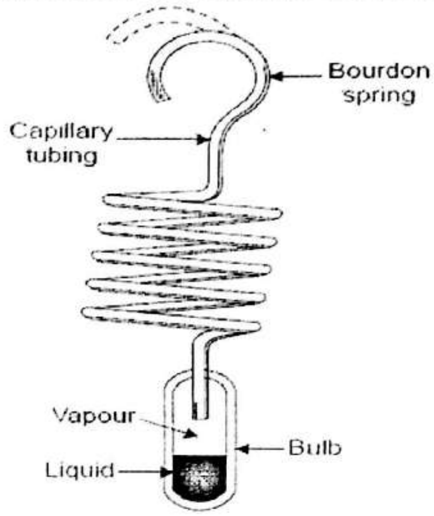
- An eye piece at one end and an objective lens at the other end.
- A power source (battery), rheostat and mill voltmeter (to measure current) connected to a reference temperature bulb.
- An absorption screen is placed in between the objective lens and reference temperature lamp. The absorption screen is used to increase the range of the temperature which can be measured by the instrument.

The red filter between the eye piece and the lamp allows only a narrow band of wavelength of around 0.65mui

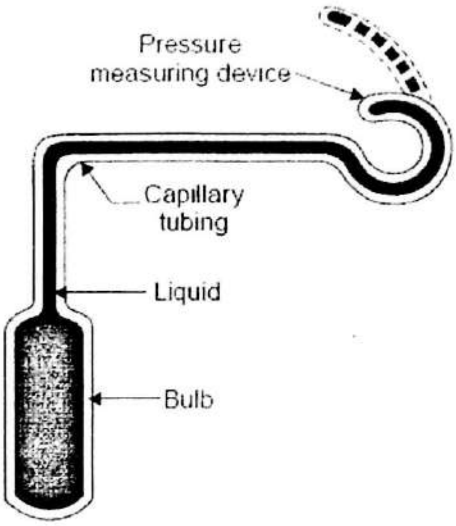
Pressure Thermometers

In pressure thermometers liquids, gases and vapours can all be used. The principle on which they work is quite simple. The fluid is confined in a closed system. In this case the pressure is a function of the temperature, so that when the fluid is heated, the pressure will rise. And the temperature can be indicated by Bourdon type pressure gauge. In general, the thermometer consists of a bulb which contains bulk of the fluid. The bulb is placed in the region whose temperature is required. A capillary tube connects the bulb to a Bourdon tube, which is graduated with a temperature scale.

(i) Vapour pressure thermometer. A schematic diagram of a vapour pressure thermometer is shown in Fig. When the bulb containing the fluid is installed in the region whose temperature is required, some of the fluid vaporizes, and increases the vapour pressure. This change of pressure is indicated on the Bourdon tube. The relation between temperature and vapour pressure of a volatile liquid is of the exponential form. Therefore, the scale of a vapour pressure thermometer will not be linear.



(ii) **Liquid-filled thermometer.** A liquid-filled thermometer is shown in Fig. In this case, the expansion of the liquid causes the pointer to move in the dial. Therefore liquids having high co-efficient of expansion should be used. In practice many liquids e.g., mercury, alcohol, toluene and glycerine have been successfully used. The operating pressure varies from about 3 to 100 bar. These types of thermometers could be used for a temperature up to 650°C in which mercury could be used as the liquid. In actual design, the internal diameter of the capillary tube and Bourdon tube is, made much smaller than that of the bulb. This is because the capillary tube is subjected to a temperature which is quite different from that of the bulb. Therefore, to minimise the effect of variation in temperature to which the capillary tube is subjected, the volume of the bulb is made as large as possible as compared with the volume of the capillary. However, large volume of bulb tends to increase time lag, therefore, a compensating device is usually built into the recording or indicating mechanism, which compensates the variations in temperature of the capillary and Bourdon tubes.



(*iii*) **Gas-filled thermometers.** The temperature range for gas thermometer is practically the same as that of liquid filled thermometer. The gases used in the gas thermometers are *nitrogen* and *helium*. Both these gases are chemically inert, have good values for their co-efficient of expansion and have low specific heats. The construction of this type of thermometer is more or less the same as mercury-thermometer in which Bourdon spring is used. The errors are also compensated likewise. The only difference in this case is that bulb is made much larger than used in liquid-filled thermometers. For good performance the volume of the bulb should be made at least 8 times than that of the rest of the system. These thermometers are generally used for pressures below 35 bar.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Define temperature and name one device and its operating principle for measuring temperature.	Jan 2015	2
Q.2	Explain the principal of temperature measurement.	june2014	2
Q.3	Explain the following properties of any measuring instrument Hysteresis, Sensitivity, Accuracy and precision, Errors, Response time.	June2011	7
Q.4	Explain the term measurement and measurement error	Dec.2011	6

Unit-02/Lecture-02

PRESSURE MEASUREMENT- [RGPV June 10,14]

Types of Pressure Measurement Devices

1. Mechanical instruments.
2. Electro-mechanical instruments.
3. Electronic instruments.

Mechanical-type Instruments

1. Manometer gauges
2. Pressure gauges

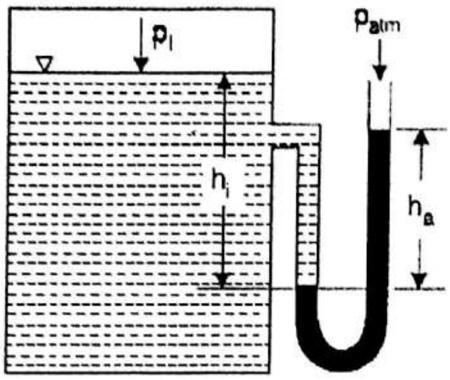
Liquid manometers

Low pressures are generally determined by manometers which employ liquid columns. It is difficult and costly to construct manometers to measure high pressures, as otherwise the liquid column will become unwieldy and temperature corrections will also be difficult. Their use is, therefore, restricted to low pressures only, and for such purposes they are quite accurate. The liquids commonly employed for manometers are mercury and water. Mercury is used for high and water for low pressures. For this purpose a liquid is suitable if it has a low viscosity, so that it can adjust itself quickly and also a low co-efficient of thermal expansion, so that density changes with temperature are minimum.

U-tube manometer :

A U-tube manometer is in the form of U-tube and is made of glass. When no pressure is applied, the height of the liquid in the two legs is the same. The pressure is then applied to one leg, whilst the other is open to the atmosphere. Under this pressure the liquid will sink in this leg and will rise in the other. As the other leg is open to the air, therefore, the pressure on this side is known, and is barometric. Now the pressure applied to the first leg can be calculated. This is explained with reference to Fig. 2.15. This consists of a water manometer.

Considering equilibrium condition, we have



$$Pa_{tm} + W_a h_a = P_l + W_l h_l$$

$$P_l = Patm + W_a h_a - W_l h_l$$

Where

P_{atm} = Atmospheric pressure,

P_l = Pressure over water surface in the container,

h_a = Height of liquid in U-tube manometer,

h_l = Difference between water surface and lower surface of the liquid in manometer,

W_a = Specific weight of liquid,

W_l = Specific weight of water.

The U-tube manometer shown in Fig. 2.16 is of the simplest form. However, readings have to be taken at two different places. Moreover, the deflection of the two columns may not be the same. To avoid this difficulty cistern or well type manometer is used.

Bourdon tube type pressure gauge

Bourdon type tube pressure gauge is used for measuring high as well as low pressures. A simple form of this gauge is shown in Fig. 2.23. In this case the pressure element consists of a metal tube of approximately elliptical cross-section. This tube is bent in the form of a segment of a circle and responds to pressure changes. When one end of the tube which is attached to the gauge case, is connected to the source of pressure, the internal pressure causes the tube to expand, whereby circumferential stress i.e., hoop tension is set up. The free end of the tube moves and is in turn connected by suitable levers to a rack, which engages with a small pinion mounted on the same spindle as the pointer. Thus the pressure applied to the tube causes the rack and pinion to move. The pressure is indicated by the pointer over a dial which can be graduated in a suitable scale.

The Bourdon tubes are generally made of bronze or nickel steel. The former is generally used for low pressures and the latter for high pressures. Depending upon the purpose for which they are required Bourdon tube gauges are made indifferent forms, some of them are :

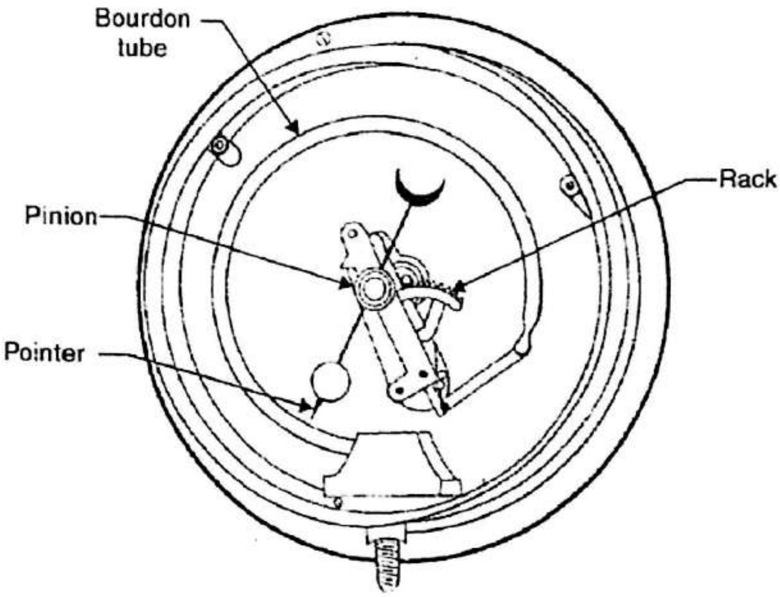
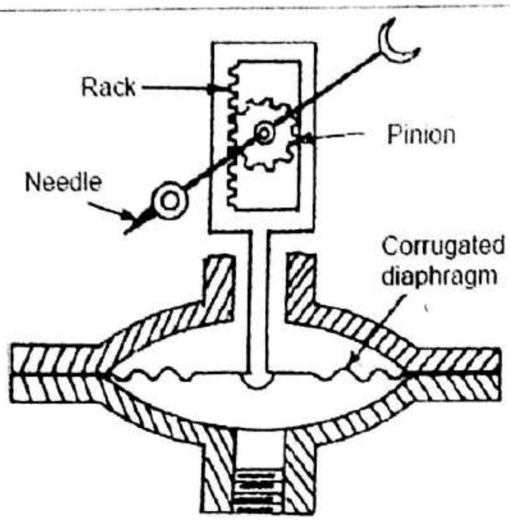


Fig. 2.23. Burdon tube pressure gauge.

(i) **Compound Bourdon tube** ...... used for measuring pressures both above and below atmospheric.
(ii) **Double Bourdon tube** ...... used where vibrations are encountered.

2. Diaphragm gauge :

This type of gauge employs a metallic disc or diaphragm instead of a bent tube. This disc or diaphragm is used for actuating the indicating device. Refer Fig. When pressure is applied on the lower side of the diaphragm, it is deflected upward. This movement of the diaphragm is transmitted to a rack and pinion. The latter is attached to the spindle of needle moving on a graduated dial. The dial can again be graduated in a suitable scale.



3.Vacuum gauge

Bourdon gauges discussed earlier can be used to measure vacuum instead of pressure. Slight changes in the design are required for this purpose. Thus, in this case, the tube is bent inward instead of outward as in pressure gauge. Vacuum gauges are graduated in millimetres of mercury below atmospheric pressure. In such cases, therefore, absolute pressure in millimetres of mercury is the difference between barometer reading and vacuum gauge reading. Vacuum gauges are used to measure the vacuum in the condensers etc. If there is leakage, the vacuum will drop. The pressure gauge installation require the following considerations :

(i) Flexible copper tubing and compression fittings are recommended for most installations.
(ii) The installation of a gauge cock and tee in the line close to the gauge is recomm- ended because it permits the gauge to be removed for testing or replacement without having to shut down the system.
(iii) Pulsating pressures in the gauge line are not required.
(iv) The gauge and its connecting line is filled with an inert liquid and as such liquid seals are provided. Trapped air at any point of gauge lines may cause serious errors in pressure reading

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Briefly explain the device used for measuring the pressure of fluid.	June 2014	2
Q.2	Explain the various pressure measurement instruments.	June 2010	10

TARQUE AND FLOW MEASUREMENT-

Dynamometer is a brake but in addition it has a device to measure the frictional resistance.
Knowing the frictional resistance, we may obtain the torque transmitted and hence the power of the engine.

Types of Dynamometers

Following are the two types of dynamometers, used for measuring the Torque and brake power of an engine.

1. Absorption dynamometers, and

2. Transmission dynamometers.

In the absorption **dynamometers,** the entire energy or power produced by the engine is absorbed by the friction resistances of the brake and is transformed into heat, during the process of measurement. But in the **transmission dynamometers,** the energy is not wasted in friction but is used for doing work. The energy or power produced by the engine is transmitted through the dynamometer to some other machines where the power developed is suitably measured.

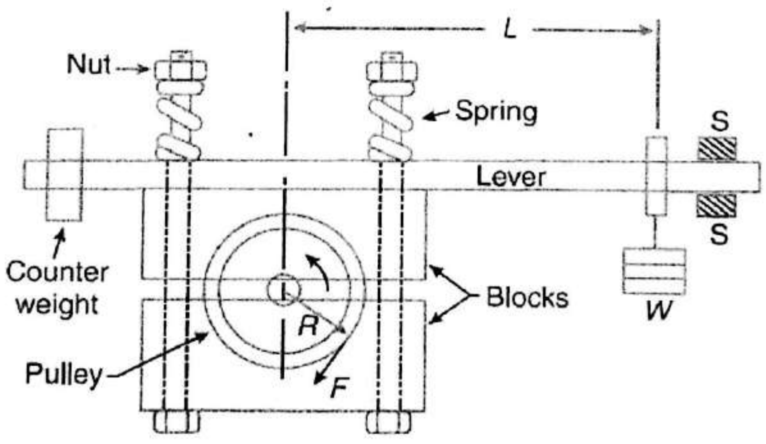
Classification of Absorption Dynamometers

The following two types of absorption dynamometers are important from the subject point of view :

1. Prony brake dynamometer, and **2.** Rope brake dynamometer.

Prony Brake Dynamometer

A simplest form of an absorption type dynamometer is a prony brake dynamometer, as shown in Fig. It consists of two wooden blocks placed around a pulley fixed to the shaft of an engine whose power is required to be measured. The blocks are clamped by means of two bolts and nuts, as shown in Fig. 19.31. A helical spring is provided between the nut and the upper block to adjust the pressure on the pulley to control its speed. The upper block has a long lever attached to it and carries a weight W at its outer end. A counter weight is placed at the other end of the lever which balances the brake when unloaded. Two stops S, S are provided to limit the motion of the lever.



When the brake is to be put in operation, the long end of the lever is loaded with suitable weights *W* and the nuts are tightened until the engine shaft runs at a constant speed and the lever is in horizontal position. Under these conditions, the moment due to the weight *W* must balance the moment of the frictional resistance between the blocks and the pulley.

Let

W = Weight at the outer end of the lever in Newton's,

L = Horizontal distance of the weight W
from the centre of the pulley in metres,
F = Frictional resistance between the blocks
and the pulley in Newton's,
R = Radius of the pulley in metres, and
N = Speed of the shaft in r.p.m.
We know that the moment of the frictional resistance
or torque on the shaft,

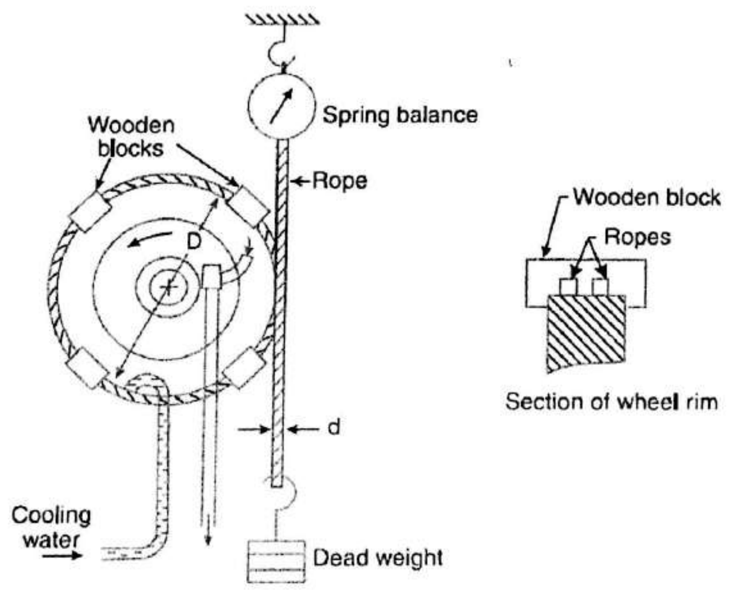
$$T = W.L = F.R \text{ N-m}$$

Rope Brake Dynamometer

It is another form of absorption type dynamometer which is most commonly used for measuring the brake power of the engine. It consists of one, two or more ropes wound around the flywheel or rim of a pulley fixed rigidly to the shaft of an engine. The upper end of the ropes is attached to a spring balance while the lower end of the ropes is kept in position by applying a dead weight as shown in Fig. In order to prevent the slipping of the rope over the flywheel, wooden blocks are placed at intervals around the circumference of the flywheel. In the operation of the brake, the engine is made to run at a constant speed. The frictional torque, due to the rope, must be equal to the torque being transmitted by the engine.

Let
W = Dead load in Newton's,
S = Spring balance reading in Newton's,
D = Diameter of the wheel in metres,
d = diameter of rope in metres, and
N = Speed of the engine shaft in r.p.m.

Net load on the brake = $(W - S)$ N



We know that distance moved in one revolution

$= \pi(D+d)$m

$\therefore$ Work done per revolution $= (W-S)\,\pi\,(D+d)$ N-m

and work done per minute $= (W-S)\,\pi\,(D+d)\,N$ N-m

$\therefore$ Brake power of the engine,

$$B.P = \text{Work done per min} / 60 \text{ watts}$$

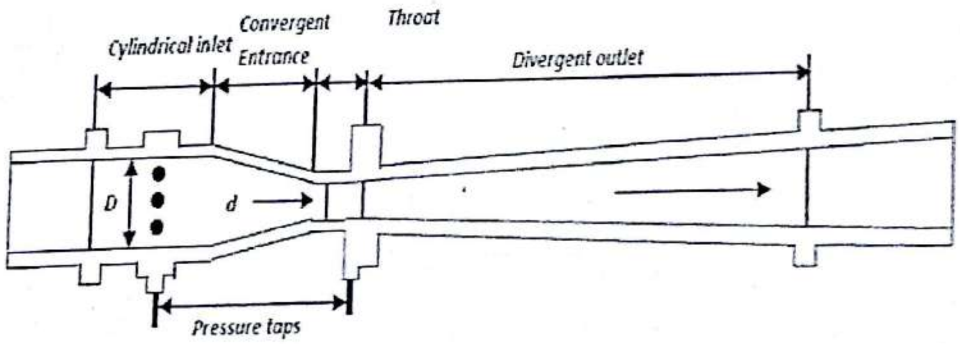
$$= (W-S)\,\pi\,(D+d)\,N/60 \text{ watts}$$

Flow Measurement

Venturi meter

Venturi meter is commonly used flow meters for measuring mass/volumetric flow rate or velocity of the flowing fluid. These flow meters are also known as variable head meters. They are categorized as *full-bore meter* as measurement of the fluid takes place when it flows through a conduit or channel.

The venturi meter has a converging conical inlet, a cylindrical throat and a diverging recovery cone. It has no projections into the fluid, no sharp corners and no sudden changes in contour. The following figure shows the venturi meter with uniform cylindrical section before converging entrance, a throat and divergent outlet. The converging inlet section decreases the area of the fluid stream, causing the velocity to increase and the pressure to decrease. The low pressure is measured in the centre of the cylindrical throat as the pressure will be at its lowest value, where neither the pressure nor the velocity will be changing. As the fluid enters the diverging section the pressure is largely recovered lowering the velocity of the fluid. The major disadvantages of this type of flow detection are the high initial costs for installation and difficulty in installation and inspection.



The *Venturi effect* is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The fluid velocity must increase through the constriction to satisfy the equation of continuity, while its pressure must decrease due to conservation of energy: the gain in kinetic energy is balanced by a drop in pressure or a pressure gradient force. An equation for the drop in pressure due to Venturi effect may be derived from a combination of Bernoulli's principle and the equation of continuity. The equation for venturi meter is obtained by applying Bernoulli equation and equation of continuity assuming an incompressible flow of fluids through manometer tubes. If V_1 and V_2 are the average upstream and downstream velocities and ρ is the density of the fluid, then using Bernoulli's equation we get,

$$\alpha_2 V_2^2 - \alpha_1 V_1^2 = \frac{2g(P_a - P_b)}{\rho} \quad \text{.......................... (1)}$$

Where $\alpha 1$ and $\alpha 2$ are kinetic energy correction factors at two pressure tap positions. Assuming density of fluid to be constant, the equation of continuity can be written as:

$$V_1 = \left(\frac{D_2}{D_1}\right)^2 V_2 \quad \text{.......................... (2)}$$

Where *D1* and *D2* are diameter of pipe and throat in meters respectively. Eliminating *V1* from equation (1) and equation (2) we get,

$$V_2 = \frac{1}{\sqrt{\alpha_2 - \alpha_1 \beta^4}} \sqrt{\frac{2(P_1 - P_2)}{\rho}} \quad \text{.......................... (3)}$$

Where *β* is the ratio of the diameter of throat to that of diameter of pipe.
If we assume a small friction lose between two pressure taps, the above equation (3) can be corrected by introducing empirical factor *Cv* and written as,

$$V_2 = \frac{C_V}{\sqrt{1-\beta^4}} \sqrt{\frac{2(P_1 - P_2)}{\rho}} \quad \text{.......................... (4)}$$

The small effect of the kinetic energy factors $\alpha 1$ and $\alpha 2$ are also taken into account in the definition of *Cv*.
Volumetric flow rate *Qa* can be calculated as:

$$Q_a = V_2 S_2 = \frac{C_V S_2}{\sqrt{1-\beta^4}} \sqrt{\frac{2(P_1 - P_2)}{\rho}} \quad \text{.......................... (5)}$$

Where, *S2* is the cross sectional area of throat in m2. Substituting *(P1 – P2) = ρgH* in above equation (5) we get,

$$Q_a = V_2 S_2 = \frac{C_V S_2}{\sqrt{1-\beta^4}} \sqrt{2g\Delta H} \quad \text{.......................... (6)}$$

Where ΔH is the manometric height difference * (specific gravity of manometric fluid – specific gravity of manometric fluid of water).

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	What is venturimeter? Derive the expression for measuring the rate of flow of fluid in a horizontal pipe?	Jan 2015	7
Q.2	Explain the principle of venturimeter with a neat sketch and derive the expression for the rate of flow of fluid through it.	June 2014	7
Q.3	What is orifice meter? Draw its diagram and give the formula used for measurement.	Jan 2015	2

Unit-02/Lecture-04

FORCE ,.STRAIN AND VELOCITY MEASUREMENT -

Force Measurement

Methods of measurement of a force

(1) Force may be measured by mechanical balancing using simple elements such as the lever

a. A platform balance is an example – of course mass is the measured quantity since acceleration is equal to the local acceleration due to gravity

(2) Simplest method is to use a transducer that transforms force to displacement

a. Example: Spring element
b. Spring element may be an actual spring or an elastic member that undergoes a strain
(3) Force measurement by converting it to hydraulic pressure in a piston cylinder device

a. The pressure itself is measured using a pressure transducer

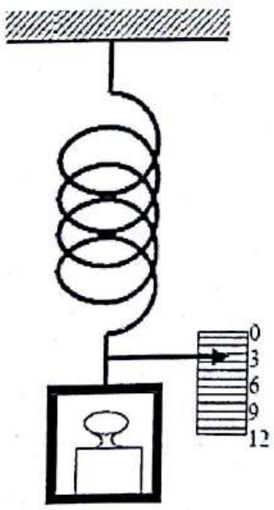
(4) Force measurement using a piezoelectric transducer

SPRING BALANCE

A spring balance is an example where a force may be converted to a displacement based on the spring constant. For a spring element (it need not actually be a spring in the form of a coil of wire) the relationship between force *F* and displacement *x* is linear and given by

$$F = K x$$

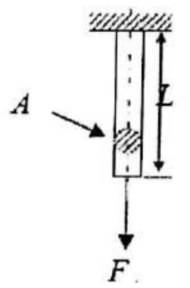
Where *K* is the spring constant. Simplest device of this type is in fact the spring balance whose schematic is shown in Figure



The spring is fixed at one end and at the other end hangs a pan. The object to be weighed is placed in the pan and the position of the needle along the graduated scale gives the weight of the object. For a coiled spring like the one shown in the illustration, the spring constant is given by

$$K = \frac{E_s D_w^4}{8 D_m^3 N}$$

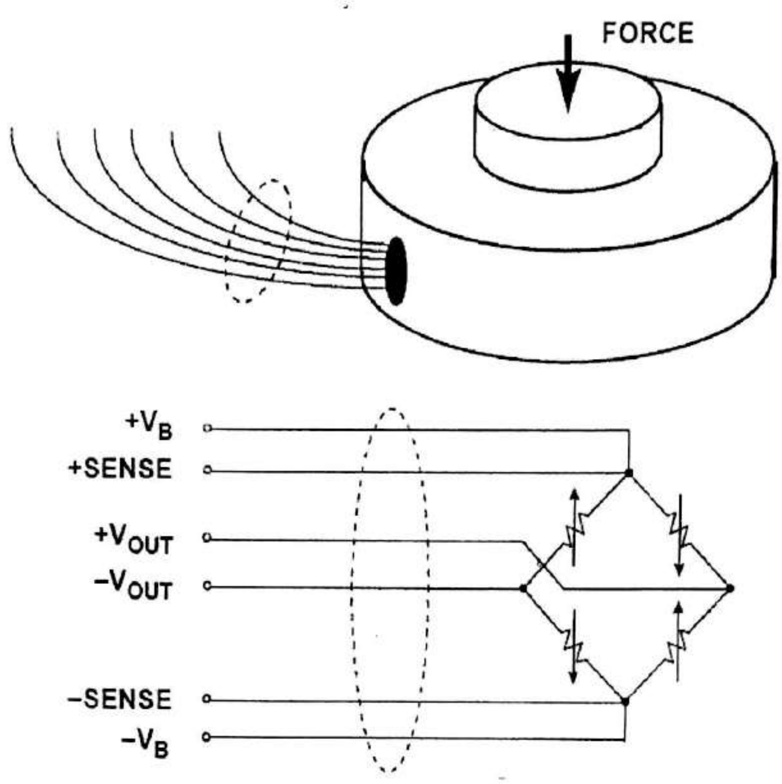
In this equation *Es* is the shear modulus of the material of the spring, *Dw* is the diameter of the wire from which the spring is wound, *Dm* is the mean diameter of the coil and *N* is the number of coils in the spring. An elastic element may be used to convert a force to a displacement. Any elastic material follows Hooke's law within its elastic limit and hence is a potential spring element. Several examples are given in Figure 49 along with appropriate expressions for the applicable spring constants. Spring constants involve *E*, the Young's modulus of the material of the element, the geometric parameters indicated in the figure. In case of an element that undergoes bending the moment of inertia of the cross section is the appropriate geometric parameter. The expressions for spring constant are easily derived and are available in any book on strength of materials.



$$K = \frac{AE}{L}$$

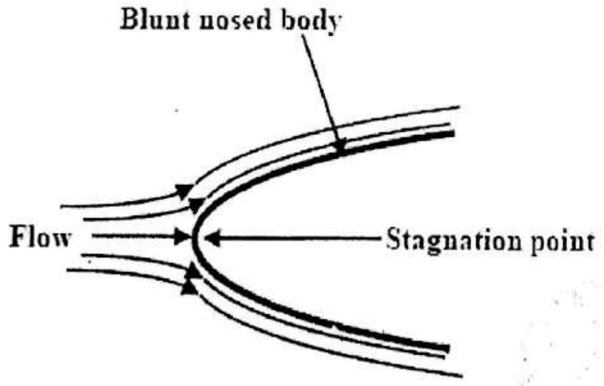
LEAD LOAD CELL

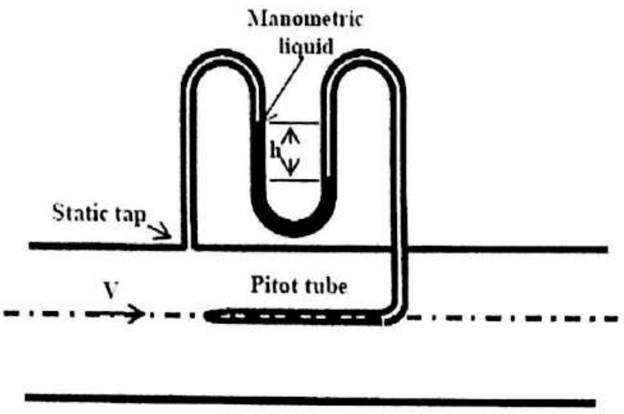
Pressures in liquids and gases are measured electrically by a variety of pressure transducers. A variety of mechanical converters (including diaphragms, capsules, bellows, manometer tubes, and Bourdon tubes) are used to measure pressure by measuring an associated length, distance, or displacement and to measure pressure changes by the motion produced. The output of this mechanical interface is then applied to an electrical converter such as a strain gage or piezoelectric transducer. Unlike strain gages, piezoelectric pressure transducers are typically used for high-frequency pressure measurements (such as sonar applications or crystal microphones).



Pitot and Pitot static tube

The basic principle of the Pitot and Pitot static tube is that the pressure of a flowing fluid will increase when it is brought to rest at a stagnation point of the probe. Figure 81 shows the streamlines in the vicinity of a blunt nosed body. We assume that, if the flow is that of a gas, like air, the velocity of the fluid is much smaller than the speed of sound in air such that density changes may be ignored. Basically the fluid behaves as an incompressible fluid. The stagnation point is located as shown. Streamlines bend past the body as shown. The pressure at the stagnation point is the stagnation pressure.





If viscous effects are negligible the difference between the stagnation pressure and the static pressure is related to the dynamic pressure which is related to the square of the velocity. Thus the velocity information is converted to a pressure difference that may be measured by a pressure measuring device such as a manometer. The basic arrangement for measuring fluid velocity using a Pitot tube is shown in Figure 98. The Pitot tube consists of bent tube of small diameter (small compared to the diameter or size of the duct) with a rounded nose. The flow is axi-symmetric and in the vicinity of the nose is like the flow depicted in Figure. The Pitot tube is connected to one limb of a U tube manometer. The other limb of the manometer is connected to a tap made on the tube walls indicated. The tube tap and the nose of the Pitot tube are roughly in the same plane. It is assumed that the wall tap senses the static pressure p of the fluid while the Pitot tube senses the stagnation pressure po of the fluid. From Bernoulli principle we have (for low speed flow, fluid velocity much less than sonic velocity in the fluid)

$$(p_o - p) = \frac{1}{2}\rho V^2$$

With ρm as the density of the manometer liquid the pressure difference is given by

$$p_o - p = (\rho_m - \rho) g h$$

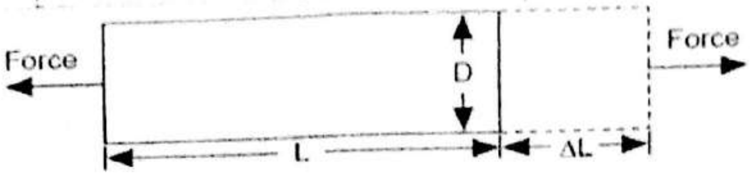
By above two relations we get...

$$V = \sqrt{2\frac{(\rho_m - \rho)}{\rho} g h}$$

Strain Measurement

Definition of strain

Strain is the amount of deformation of a body due to an applied force. More specifically, strain (e) is defined as the fractional change in length, as shown in Figure below.



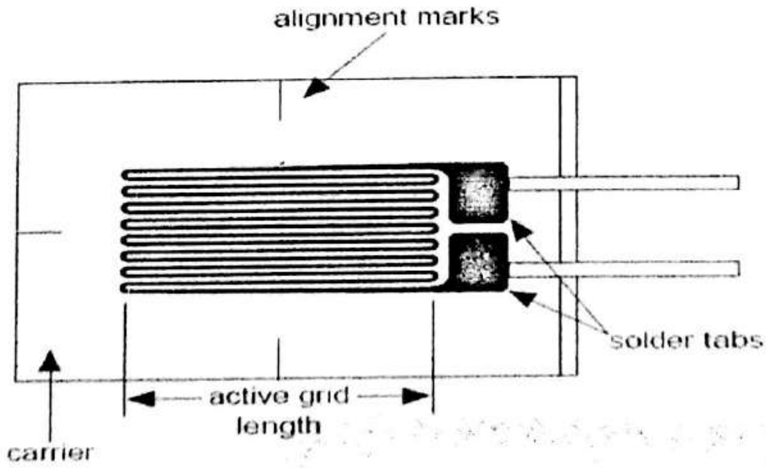
$$\varepsilon = \frac{\Delta L}{L}$$

Definition of Strain

Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as micro strain (me), which is e ´ 10⁻⁶. When a bar is strained with a uniaxial force, as in Figure 1, a phenomenon known as Poisson Strain causes the girth of the bar, D, to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio. The Poisson's Ratio n of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction

Strain Gauge

While there are several methods of measuring strain, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. For example, the piezoresistive strain gauge is a semiconductor device whose resistance varies nonlinearly with strain. The most widely used gauge, however, is the bonded metallic strain gauge. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction. The cross sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance. Strain gauges are available commercially with nominal resistance values from 30 to 3000 W, with 120, 350, and 1000 W being the most common values.



It is very important that the strain gauge be properly mounted onto the test specimen so that the strain is accurately transferred from the test specimen, though the adhesive and strain gauge backing, to the foil

itself. Manufacturers of strain gauges are the best source of information on proper mounting of strain gauges. A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor (GF). Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in
length (strain):

$$GF = \frac{\Delta R / R}{\Delta L / L} = \frac{\Delta R / R}{\varepsilon}$$

The Gauge Factor for metallic strain gauges is typically around 2.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1			
Q.2			

Unit-02/Lecture-05

Error and uncertainty analysis - [RGPV Dec 12]

Types of error

Generally the errors incurred in any measurement can be considered to be of two distinct types, those which should not occur and can be eliminated by careful work and attention to detail, and those which are inherent in the measuring process.

1. Calamitous or Catastrophic Errors
These are errors of large magnitude having two fundamental causes:
(a) Misreading an instrument. A micrometer is misread as 6•28 mm or 5•78 mm instead of the correct reading of 5•28 mm.
(b) Arithmetic errors. These are usually errors of addition. A simple check is to make the calculation twice using different methods, e.g. add a column of figures twice, first upwards then downwards, to ensure that the two results coincide.
In most cases such errors give a result so different from that expected that it is obvious when an error has occurred, and the measurement is repeated and the error detected. This may not always be so, however, and such errors can only be avoided

2. Alignment Errors
This type of error occurs when the measuring instrument is misaligned relative to the work piece. It usually results in the measured dimension **M** being related to the actual dimension **D** by one of the trigonometrical ratios. Hence such errors are known as trigonometrical or cosine errors. A simple example is shown in Fig. 1.1, where a dial gauge is inclined at angle **θ** to the required line of measurement.

3. Errors Due to Ambient Conditions
Most measurements are affected to a greater or lesser extent by the environment in which they are carried out. The most important condition is the temperature, both of the work piece and of its surroundings. The international standard temperature of measurement is **20°C** (68°F) and the ambient temperature should be maintained at this level. However carefully this is controlled, it is to no avail if the temperature of the work piece is allowed to vary. Handling a gauge changes its temperature, so it should be handled as little as possible, and having been handled, allowed stabilizing. Where measurements are being made to a high order of accuracy

a time of **20** minutes per **25** mm length of gauge is recommended. During a measurement it is best if all of the components used are left standing on a cast iron surface plate rather than a plastic or wooden bench top. The cast iron, being a good conductor, acts as a heat sink and dissipates temperature differentials more rapidly.
There are two situations to be considered when the effects of temperature are to be discussed:

(a) **Direct measurement**. Consider a gauge block being measured directly by interferometry. Here the effect of using a non-standard temperature produces a proportional error:

Error = l α (t -- ts)

(b) Comparative measurement. If we consider two gauges whose expansion coefficients are respectively **α1** and **α2**, then the error due to a non-standard temperature will be

(a) **Error = l (α1 - α 2)(t - ts)**

4. Errors Due to Elastic Deformation

Any elastic body subject to a load will undergo elastic deformation. The magnitude of the deformation will depend upon the magnitude of the load, the area of contact and the mechanical properties of the materials in contact. It is therefore necessary to ensure that the measuring loads are the same in comparative measurement.

In most instruments used in fine measurement, comparators, bench micrometers, etc., the measuring pressure is reasonably constant, and it follows that the greatest difficulty is due to different types of contact when first setting an instrument to a gauge and then taking a reading on the work under test.

Scale Errors

If the scale against which a measurement made is in error, then obviously that measurement will be in error. This can only be overcome by calibrating the instrument scale against known standards of length over its whole length.

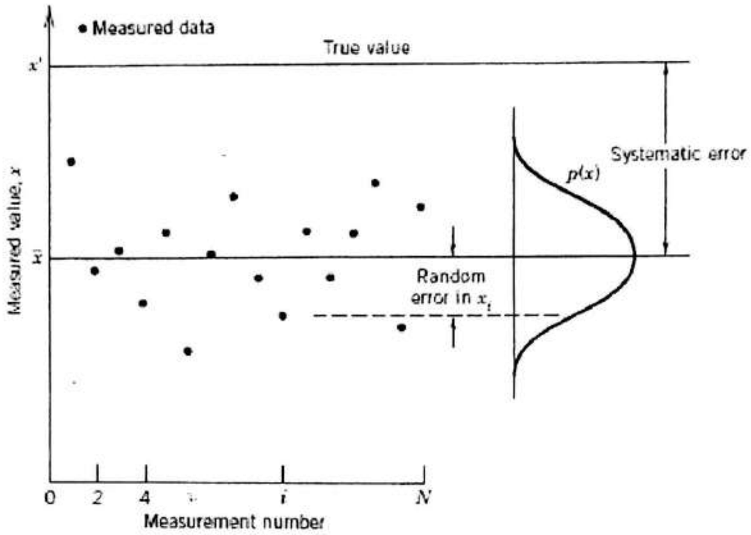
In comparative measurements the effects of scale errors are reduced by using as short a length of scale as possible, by choosing a setting master whose size is as close to that of the gauge being checked as is conveniently possible.

Measuring Errors

The different types of error discussed above are cumulative, and in some cases a further amount must be added to allow for sensitivity of touch or feel. This will depend upon the type of instrument being used, and in general the effect is eliminated with comparators.

Uncertainty Analysis

Errors are a property of the measurement. Measurement is the process of assigning a value to a physical variable based on a sampling from the population of that variable. Error causes a difference between the value assigned by measurement and the true value of the population of the variable. Measurement errors are introduced from various elements, for example, the individual instrument calibrations, the data set finite statistics, and the approach used. But because we do not know the true value and we only know the measured values, we do not know the exact values of errors. Instead, we draw from what we do know about the measurement to estimate a range of probable error. This estimate is an assigned value called the uncertainty. The uncertainty describes an interval about the measured value within which we suspect that the true value must fall with a stated probability. Uncertainty analysis is the process of identifying, quantifying, and combining the errors. Uncertainty is a property of the result. The outcome of a measurement is a result, and the uncertainty quantifies the quality of that result. Uncertainty analysis provides a powerful design tool for evaluating different measurement systems and methods, designing a test plan, and reporting uncertainty. This chapter presents a systematic approach for identifying, quantifying, and combining
the estimates of the errors in a measurement. While the chapter stresses the methodology of analyses, we emphasize the concomitant need for an equal application of critical thinking and professional judgment in applying the analyses. The quality of an uncertainty analysis depends on the engineer's knowledge of the test, the measured variables, the equipment, and the measurement procedures (1). Errors are effects, and uncertainties are numbers. While errors are the effects that cause a measured value to differ from the true value, the uncertainty is an assigned numerical value that quantifies the probable range of these errors.



Distribution of errors on repeated measurements.

Certain assumptions are implicit in an uncertainty analysis:

1. The test objectives are known and the measurement itself is a clearly defined process.
2. Any known corrections for systematic error have been applied to the data set, in which case the systematic uncertainty assigned is the uncertainty of the correction.
3. Except where stated otherwise, we assume a normal distribution of errors and reporting of uncertainties.
4. Unless stated otherwise, the errors are assumed to be independent (uncorrelated) of each other. But some errors are correlated, .
5. The engineer has some "experience" with the system components.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Discuss the different source of errors in the act of taking measurement.	Dec.2012	7
Q.2	Explain the term measurement and measurement error	Dec.2011	6
Q.3			

Unit-02/Lecture-06

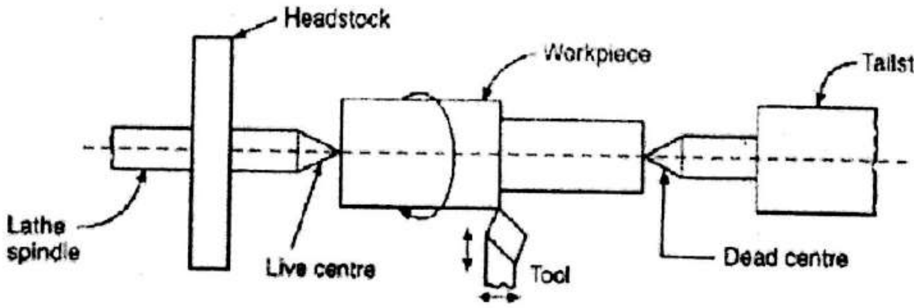
LATHE MACHINE - [RGPV June 11,13,14 Dec 12,13]

working principle of lathe

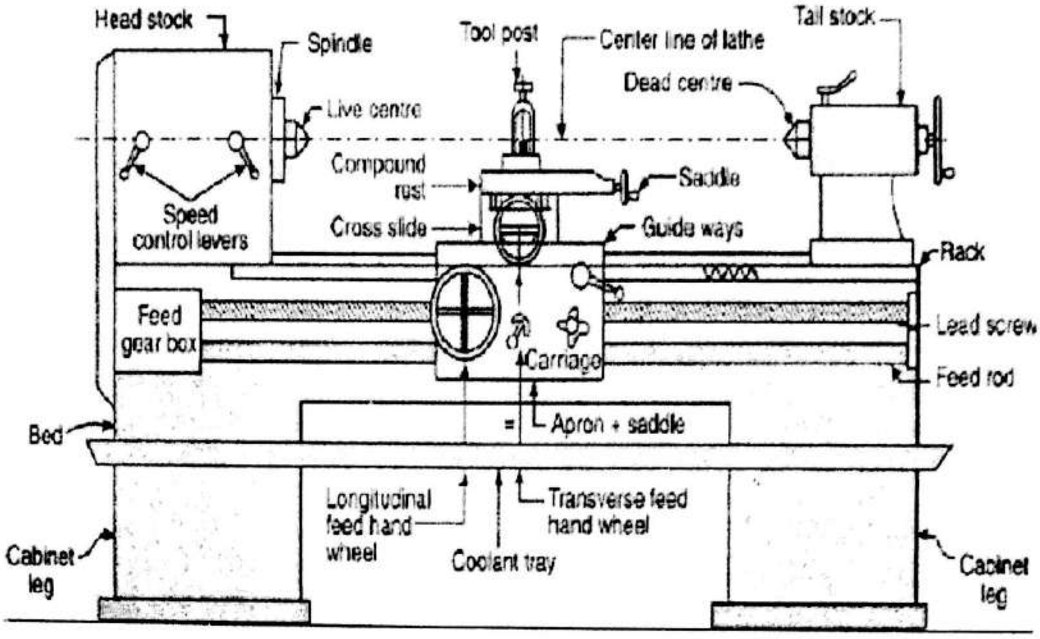
The lathe machine works on the principle that, a cutting tool can remove material when it is moved against a rotating work piece. This is accomplished by rotating the work piece between two rigid and strong supports, while the cutting tool is fed against it. the principle of operation is shown in figure

When the tool is moved against the rotating work piece, the excess material is removed from the work piece in the form of fine chips. the type of surface produced depends on the Movement of the tool with respect to the axis of rotation of the workpiece.

- When the tool moves parallel to the axis of rotation of the work piece, a cylindrical surface is produced.
- When the tool moves perpendicular to the axis of rotation of the work piece, a flat surface is produced.
- When the tool moves at an angle to the axis of rotation of the work piece, a tapered surface can be produced.



parts of a lathe:



1. Bed: the bed is a heavy, rugged casting in which are mounted the working parts of the lathe. it carries the headstock and tail stock for supporting the work piece and provides a base for the movement of carriage assembly which carries the tool.

2. Legs: the legs carry the entire load of machine and are firmly secured to floor by foundation bolts.

3. Headstock: the headstock is clamped on the left hand side of the bed and it serves as housing for the driving pulleys, back gears, headstock spindle, live centre and the feed reverse gear. The headstock spindle is a hollow cylindrical shaft that provides a drive from the motor to work holding devices.

4. Gear box: the quick-change gear-box is placed below the headstock and contains a number of different sized gears.

5. Carriage: the carriage is located between the headstock and tailstock and serves the purpose of supporting, guiding and feeding the tool against the job during operation. the main parts of carriage are:

a). the saddle is an h-shaped casting mounted on the top of lathe ways. it provides support to cross-slide, compound rest and tool post.

b). the cross slide is mounted on the top of saddle, and it provides a mounted or automatic cross movement for the cutting tool.

c). the compound rest is fitted on the top of cross slide and is used to support the tool post and the cutting tool.

d). the tool post is mounted on the compound rest, and it rigidly clamps the cutting tool or tool holder at the proper height relative to the work centre line.

e). the apron is fastened to the saddle and it houses the gears, clutches and levers required to move the carriage or cross slide. The engagement of split nut lever and the automatic feed lever at the same time is prevented she carriage along the lathe bed.

6. Tailstock: the tailstock is a movable casting located opposite the headstock on the ways of the bed. The tailstock can slide along the bed to accommodate different lengths of work piece between the centres. A tailstock clamp is provided to lock the tailstock at any desired position. The tailstock spindle has an internal taper to hold the dead centre and the tapered shank tools such as reamers and drills.

lathe operations:

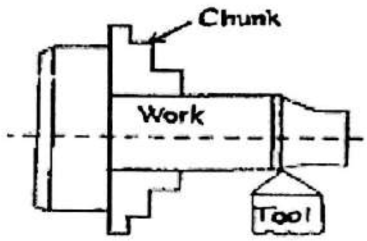
the operations performed on a lathe machine are:

1. Plain turning or cylindrical turning.

2. facing
3. knurling
4. drilling
5. threading
6. taper turning
7. parting

plain turning:

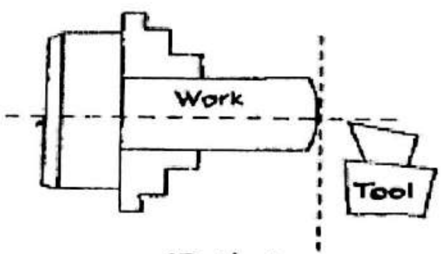
It is the operation of removing excess amount of material from the work piece to produce a cylinder work piece. in this operation, shown in fig., the work is held either in the chuck or between centres, the cutting tool is fed against the revolving work piece and is then moved parallel to the lathe axis so as to produce a cylindrical surface.



(Plain turning)

facing:

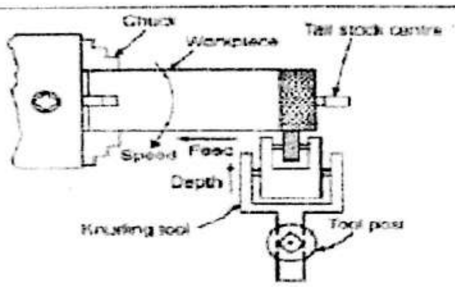
It is the operation for generating a flat surface at the end of the work piece. In this operation, as shown in fig., the work piece is held in the chuck and the facing tool is fed from the centre of the work piece towards the outer surface or from the outer surface to the centre, with the help of a cross-slide. facing is also carried out to reduce or cut the work piece to the required length.



(Facing)

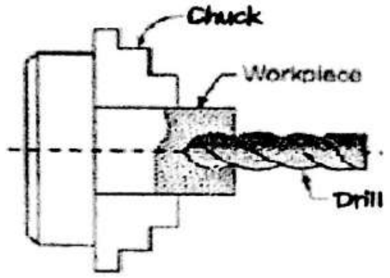
knurling

It is the process carried out on a lathe, where a visually-attractive diamond shaped pattern is cut or rolled on the surface of metallic parts. In this operation, as shown in fig., the work piece is held rigidly between two centres, the knurling tool is pressed against the rotating work piece and pressure is slowly increased until the tool produces a pattern on the work piece. The surface on the work piece formed by knurling is used for applications where grip is required to hold the part.



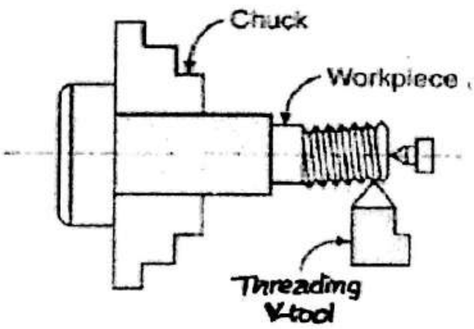
drilling

It is the operation of producing a cylindrical hole in a work piece with the help of a drill. In this operation, as shown in fig., the work piece is held in the tapered hole of the tail stock sleeve and is fed into the rotating work piece, by rotating the tail stock hand wheel.



thread cutting

It is a operation for cutting screw threads on metallic parts. In this operation, as shown in fig., the work piece is held in between the two centres, the cutting tool is mounted on the tool post and the carriage is connected to the lead screw with the help of a split nut. The rotation of the lead screw gives the required motion to the carriage relative to the rotation of the work piece. The depth of cut is selected and the tool is made to move parallel to the axis of rotation of the work piece by means of automatic arrangement. By disengaging split nut or half nut, the carriages brought back to its initial position to start another cut.



taper turning

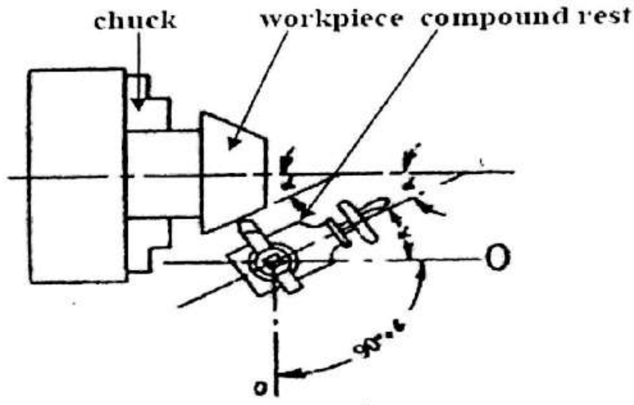
it is the operation of producing a conical surfaces on the work pieces. a taper can be produced by any one of the following methods.

i. by swivelling the compound rest

ii. by off-setting the tailstock

iii. by using a taper turning attachment

iv. by form tool method



S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain the construction and working principle of a simple lathe machine.	June 2014	7
Q.2	Give type of lathe. Name the various operations which can be performed on the lathe machine. what are the advantages of using a taper turning attachment.	Dec 2013	7
Q.3	With the help of a simple sketch, explain different components of Lathe machine.	June 2013	7
Q.4	Explain the construction and working principle of a lathe machine with neat sketch.	Dec.2012	7

Unit-02/Lecture-06

Vernier callipers and Micrometer - [RGPV June 12,13,14]

The precision of length measurements may be increased by using a device that uses a sliding vernier scale. Two such instruments that are based on a vernier scale which you will use in the laboratory to measure lengths of objects are the vernier callipers and the micrometer screw gauge. These instruments have a main scale (in millimetres) and a sliding or rotating vernier scale.

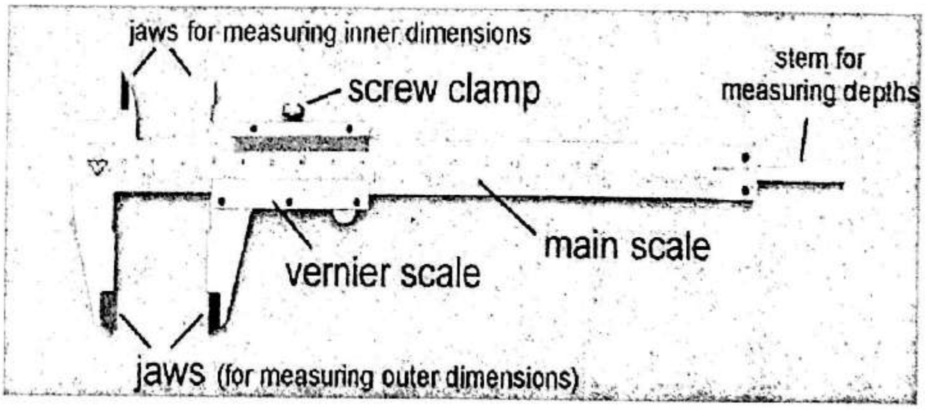
The vernier:

A Typical vernier callipers is shown in figure. To use this kind of device we need to follow the steps below:

1- To measure outer dimensions of an object, the object is placed between the jaws, which are then moved together until they secure the object.

2- The first significant figures are read immediately to the left of the "zero" of the vernier scale.

3- The remaining digits are taken from the vernier scale and placed after the decimal point of the main reading. This remaining reading corresponds to the division that lines up with any main scale division. Only one division on the vernier scale coincides with one on the main scale. See figures



Reading on the vernier callipers

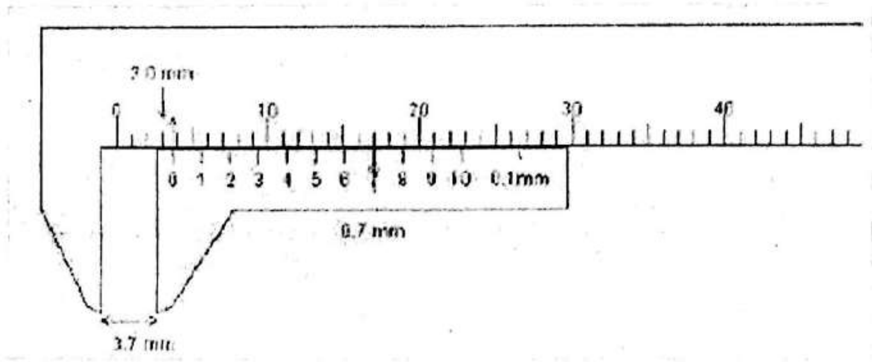


Figure   The reading here is 3.7 mm.

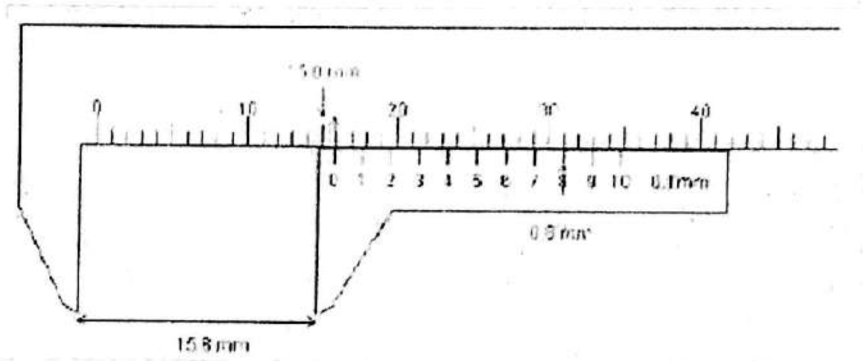
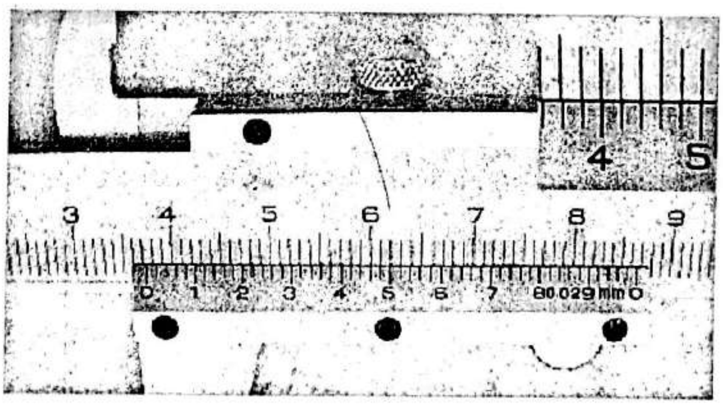


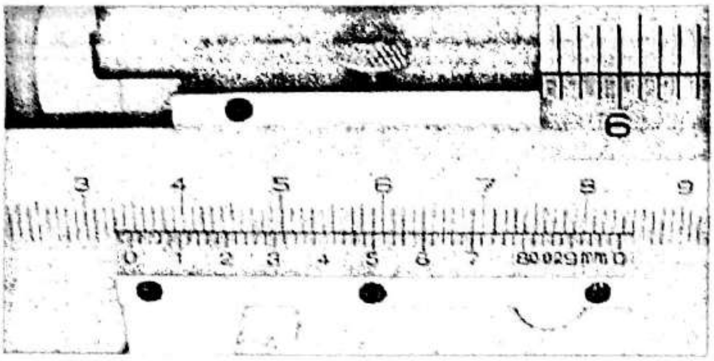
Figure   The reading here is 15.8 mm.

Some examples:

Note that the important region of the vernier scale is enlarged in the upper right hand corner of each figure.



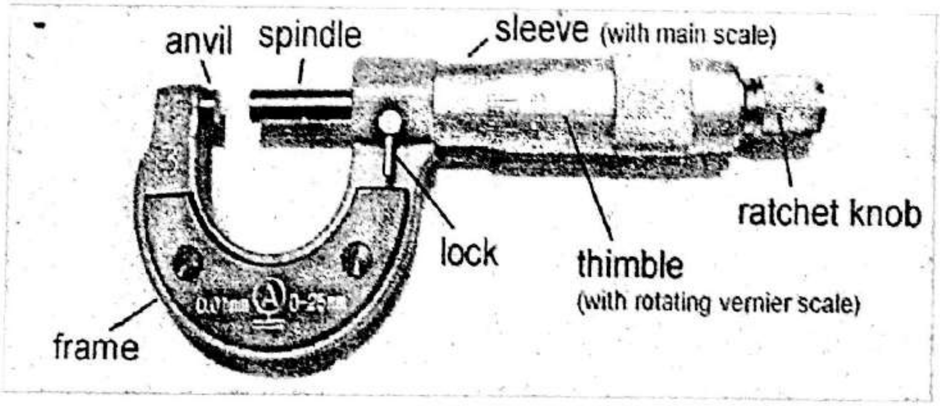
In above figure, the first significant figures are taken as the main scale reading to the left of theVernier zero, i.e. 37 mm. The remaining two digits are taken from the vernier scale reading that lines up with any main scale reading, i.e. 46 on the vernier scale. Thus the reading is 37.46 mm.



In figure 5 above, the first significant figures are taken as the main scale reading to the left of the vernier zero, i.e. 34 mm. The remaining two digits are taken from the vernier scale reading that lines up with any main scale reading, i.e. 60 on the vernier scale. Note that the zero must be included because the scale can differentiate between fiftieths of a millimetre. Therefore the reading is 34.60 mm.

micrometer screw gauge

The micrometer screw gauge is used to measure even smaller dimensions than the vernier callipers. The micrometer screw gauge also uses an auxiliary scale (measuring hundredths of a millimetre) which is marked on a rotary thimble. Basically it is a screw with an accurately constant pitch (the amount by which the thimble moves forward or backward for one complete revolution). The rotating thimble is subdivided into 50 equal divisions. The thimble passes through a frame that carries a millimetre scale graduated to 0.5 mm. The jaws can be adjusted by rotating the thimble using the small ratchet knob. The thimble must be rotated through two revolutions to open the jaws by 1 mm.



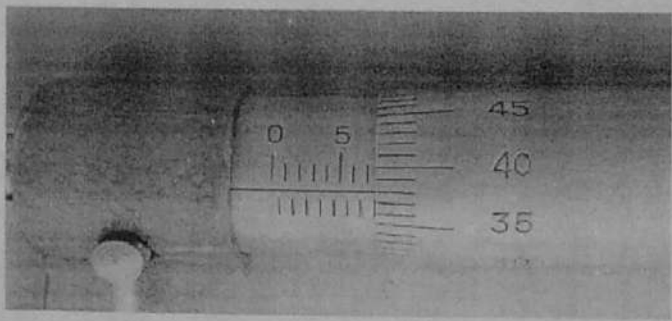
To use this kind of device we need to follow the steps below:

1- Place the object to be measured between the jaws and the thimble is rotated using the ratchet until the object is secured.

2- The first significant figure is taken from the last graduation showing on the sleeve directly to the left of the revolving thimble. Note that an additional half scale division (0.5 mm) must be included if the mark below the main scale is visible between the thimble and the main scale division on the sleeve.

3- The remaining two significant figures (hundredths of a millimetre) are taken directly from the thimble opposite the main scale. See the examples below.

In figure 11 the last graduation visible to the left of the thimble is 7 mm and the thimble lines up with the main scale at 38 hundredths of a millimeter (0.38 mm); therefore the reading is 7.38 mm.

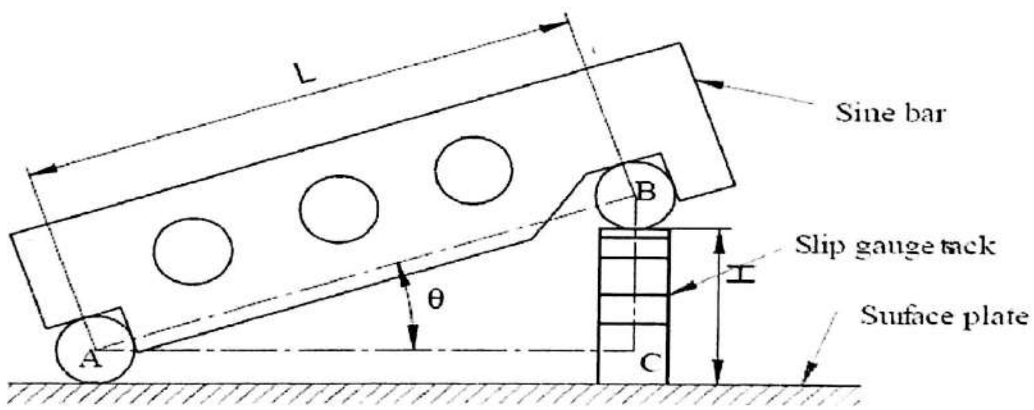


S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain the operating procedure of vernier calliper.	Jan 2015	3
Q.2	Describe vernier calliper with neat sketch..	June 2014	3
Q.3	What is the use of micrometer? Explain its working.	June 2013	7
Q.4	Explain the construction and uses of the following measuring instrument. Dial gauge, Micrometer	June 2012	14
Q.5	Explain the micro meter and its working	Dec.2012	7

Unit-02/Lecture-07

Sine Bar and Combination set - [RGPV June 10,13, Dec 13]

Sine bars are made from high carbon, high chromium, corrosion resistant steel which can be hardened, ground & stabilized. Two cylinders of equal diameters are attached at the ends as shown in fig. The distance between the axes can be 100, 200 & 300 mm. The Sine bar is designated basically for the precise setting out of angles and is generally used in conjunction with slip gauges & surface plate. The principle of operation relies upon the application of Trigonometry.

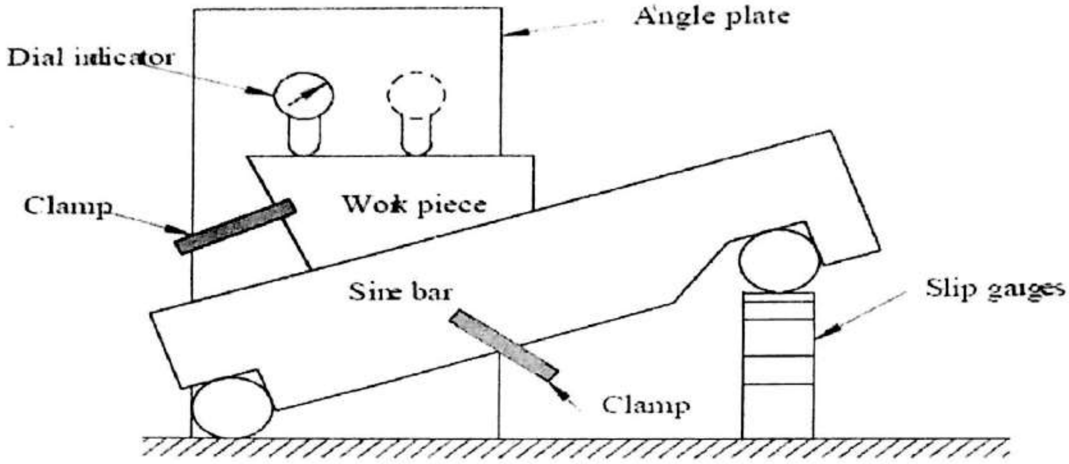


In the above fig, the standard length AB (L) can be used & by varying the slip gauge stack (H), any desired angle q can be obtained as,

$$\theta=\sin^{-1}(H/L)$$

Sine Bar

For checking unknown angles of a component, a dial indicator is moved along the surface of work and any deviation is noted. The slip gauges are then adjusted such that the dial reads zero as it moves from one end to the other.



Limitations of Sine bars:

The accuracy of sine bars is limited by measurement of centre distance between the two precision rollers & hence it cannot be used as a primary standard for angle measurements.

Sine principle is fairly reliable at angles less than 15o, but becomes inaccurate as the angle increases.

For angles exceeding 45°, sine bars are not suitable for the following reasons:

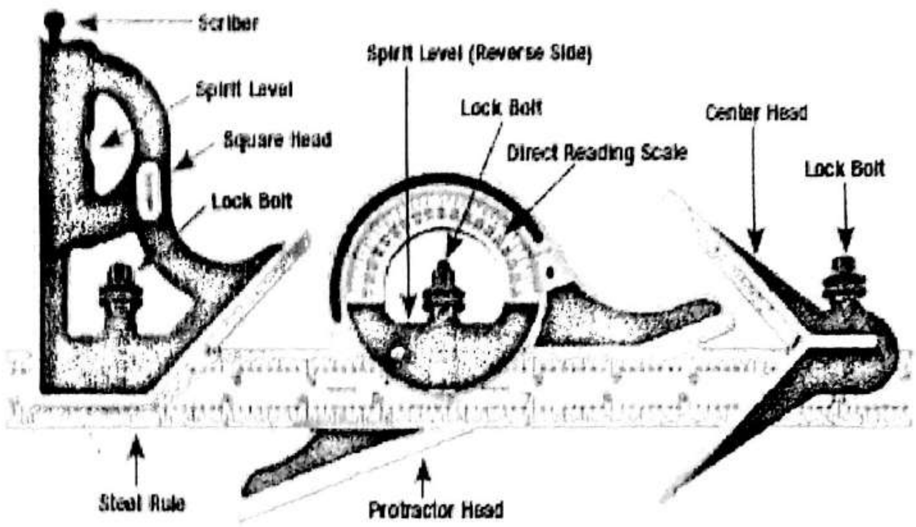
1. The sine bar is physically clumsy to hold in position.
2. The body of the sine bar obstructs the gauge block stack, even if relieved.
3. Slight errors of the sine bar cause large angular errors.
4. Long gauge stacks are not nearly as accurate as shorter gauge blocks.
5. A difference in deformation occurs at the point of roller contact supporting the surface and to the gauge blocks, because at higher angles, the load is shifted more towards the fulcrum roller.

Combination set

Description and Components

The combination square includes a hardened steel graduated rule and movable combination square and mitre head with spirit level and scriber. The square head has a precision ground 90° square face and a 45° mitre face. It is a highly versatile layout tool for scribing right angles and parallel lines, and a measuring tool that can be used as a tri-square, mitre, depth gage, height gage, and level. The Centre Head is an available attachment that provides an easy means of accurately locating the centre of cylindrical or square work.

The Protractor Head is another available attachment. It has revolving turrets with direct-reading double graduations, a full 0 to 180° in opposite directions. This permits accurate and quick direct reading of angles above or below the blade. Complete Sets are available including the rule and all three heads in a fitted case.



S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Write a short note on i) Combination set ii) Sine bar	Jan 2015	7
Q.2	With the help of a neat sketch explain the working of a Combination set, mentioning its uses. Also give a neat sketch of a Sine bar set up for measuring an angle of a work piece.	Dec. 2013	7
Q.3	Explain the use of sine bar.	June 2013	7
Q.4	Find out the angle of workpiece if consecutive height of two ends of a sine bar from the surface plate is given as 10 cm and 5 cm. The length of sine bar is 10 cm.	June2010	10
Q.5	What is the sine bar? Explain its use with the help of neat diagram and explain.	June2010	10
Q.6	Explain the construction and use of a combination set.	Dec.2012	7

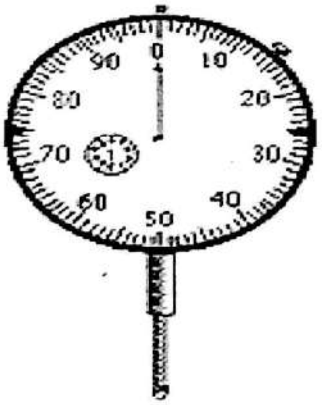
Unit-02/Lecture-08

Dial gauge and Milling machine - [RGPV June 10]

Dial Indicators are instruments used to accurately measure a small distance. The measurement results are displayed in a magnified way by means of a dial. They may be used to check the variation in tolerance during the inspection process of a machined part, measure the deflection of a beam or ring under laboratory conditions, as well as many other situations where a small measurement needs to be registered or indicated.

Applications

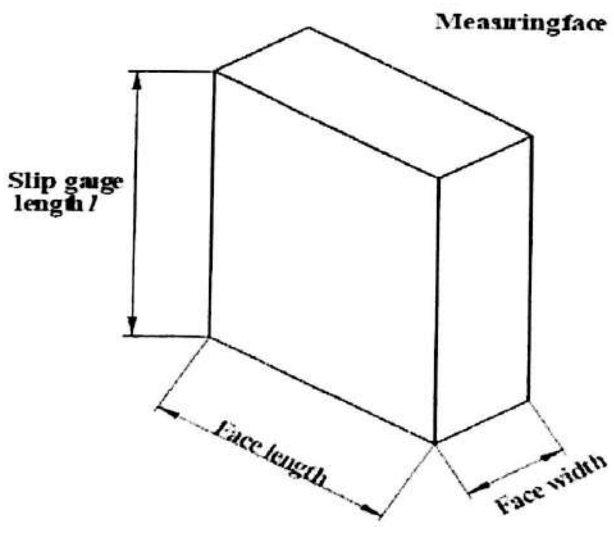
- In a quality environment to check for consistency and accuracy in the manufacturing process.
- On the *workshop floor* to initially set up or calibrate a machine, prior to a production run.
- By toolmakers (moldmakers) in the process of manufacturing precision tooling.
- In metal engineering workshops, where a typical application is the cantering of a lathe's work piece in a four jaw chuck. The DTI is used to indicate the *run out* (the misalignment between the work piece's axis of rotational symmetry and the axis of rotation of the spindle) of the work piece, with the ultimate aim of reducing it to a suitably small range using small chuck jaw adjustments.
- In areas other than manufacturing where accurate measurements need to be recorded, eg:- physics.



The dial indicator typically consist of a graduated dial and needle to record the minor increments, with a smaller embedded clock face and needle to record the number of needle rotations on the main dial. They may be graduated to record measurements of between 0.001" down to 0.00005" for more accurate usage. The dial face can be rotated to any position, this is used to orient the face towards the user as well as *set* the zero point, there will also be some means of incorporating limit indicators (the two metallic tabs visible in the right image, at 90 and 10 respectively), these limit tabs may be rotated around the dial face to any required position. The dial indicators are normally set up in a fixture (possibly a magnetic base) which would secure the dial indicator and allow its adjustment to read zero at the optimal size of a sample part.

SLIP GAUGES

Slip gauges are rectangular blocks of steel having cross section of 30 mm face length & 10 mm face width as shown in fig.

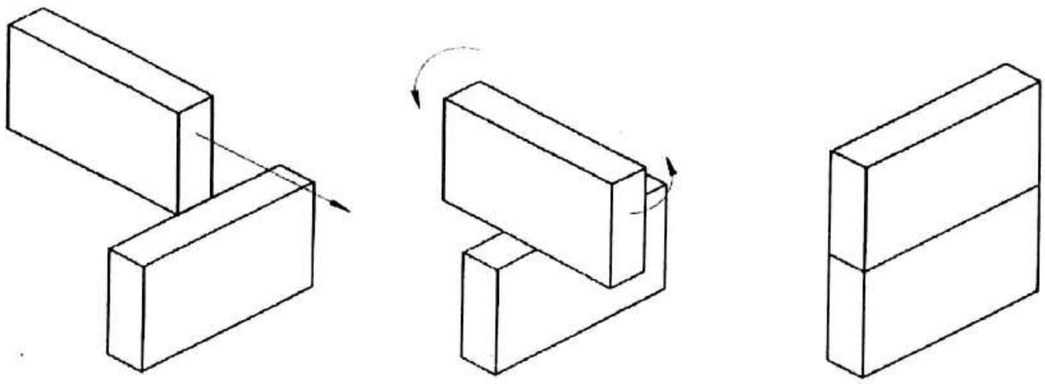


Slip gauges are blocks of steel that have been hardened and stabilized by heat treatment. They are ground and lapped to size to very high standards of accuracy and surface finish. A gauge block (also known Johansson gauge, slip gauge, or Jo block) is a precision length measuring standard consisting of a ground and lapped metal or ceramic block. Slip gauges were invented in 1896 by Swedish machinist Carl Edward Johansson.

Protector Slips:
In addition, some sets also contain protector slips that are 2.50mm thick and are made from a hard, wear resistant material such as tungsten carbide. These are added to the ends of the slip gauge stack to protect the other gauge blocks from wear. Allowance must be made of the thickness of the protector slips when they are used.

Wringing of Slip Gauges:
Slip gauges are wrung together to give a stack of the required dimension. In order to achieve the maximum accuracy the following precautions must be taken.

- Use the minimum number of blocks.
- Wipe the measuring faces clean using soft clean chamois leather.
- Wring the individual blocks together by first pressing at right angles, sliding & then twisting.



Milling machine
Milling machine is a machine tool in which metal is removed by means of a rotating cutter with multiple number of teeth (or multipoint). Each teeth has cutting edge which removes metal from work piece. The feed and depth of cut to the job is provided by feeding the job to the cutter, longitudinally, transversely or vertically.

- **Up Milling and Down Milling**

When cutter rotates against the direction of feed of job then it is called Up or Conventional milling.
When cutter rotates in the same direction as feed of job then it is called Down milling/Climb milling.

- **Common operations performed on Milling Machine**

Plain milling, Face milling, Angular milling, Gear milling, Form milling, Milling slots, Keyways etc.

- **Principal parts of Milling machine are shown in Fig.**

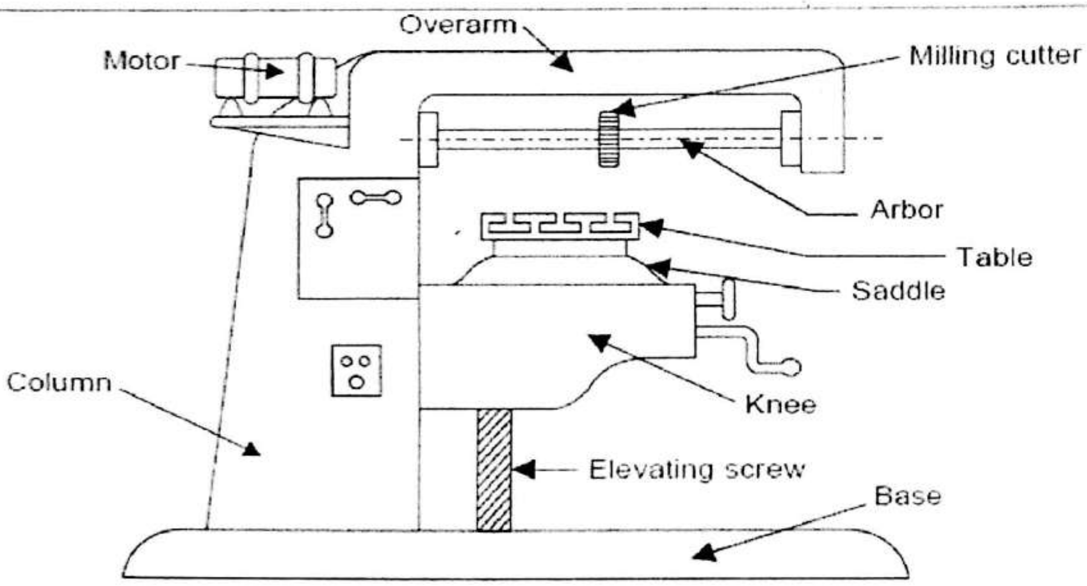


Fig. Milling Machine.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain the milling machine.	June 2010	10
Q.2			

Unit-02/Lecture-09

Shaper and Drilling machine - [RGPV June 10,11]

Introduction

Shaper is a reciprocating type machine tool which is primarily intended to produce flat surfaces. The surfaces may be horizontal, vertical on inclined. This machine involves the use of a single point cutting tool similar to a tool used in lathe machine. Tool is held in the tool post mounted at the end of ram. Workpiece is held in a vice or clamed directly on table. The ram reciprocates in to and fro direction and cutting of material takes place during forward stroke while the return stroke is idle. Return stroke time is less as compared to forward stroke and this is obtained by a quick return mechanism. Feed is provided by moving job relative to tool in a direction perpendicular to the movement of ram. Depth of cut is adjusted by moving tool downward towards the work piece.

Principal parts of a Shaper machine are shown in Fig.

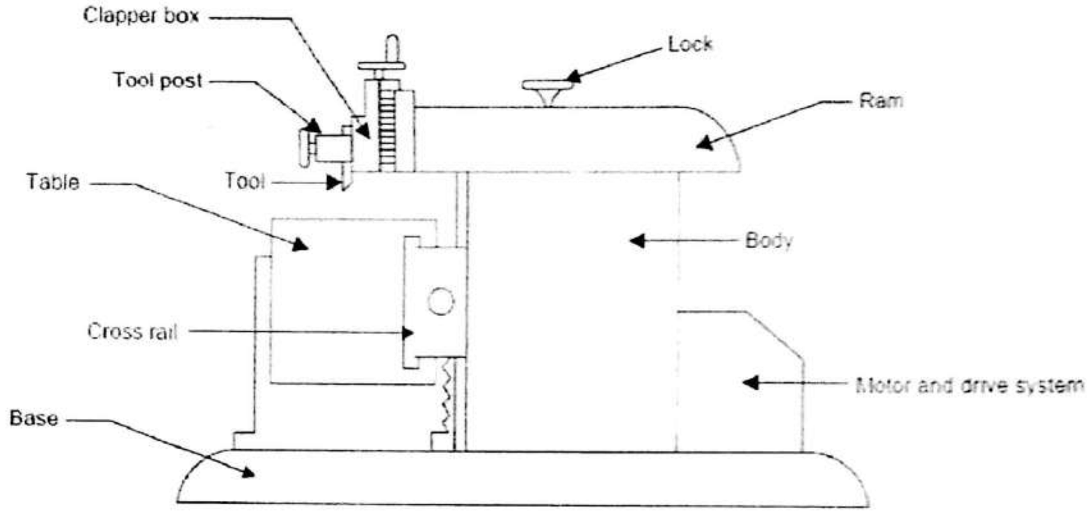


Fig. Shaper Machine.

Drilling Machine

Drilling machine is used to produce or generate a round hole in the work piece. The tool used for drilling holes is called Drill. The Drill is placed in the chuck of the machine which rotates about its axis. The linear motion is given to the drill towards the work piece. A tap is a tool used for making internal threads. The taps are provided with cutting edges and three or four flutes cut across it, so that when it is screwed into a hole, it cuts an internal thread. These are made in sets of three. First use taper tap, then medium tap and then bottoming or plug tap. These are made of high carbon steel or high speed steel and hardened and tempered.

Drill machine operation

The common operations performed on drilling machine are drilling, boring, reaming, tapping, counter boring etc.

Principal parts of the drilling machine are shown in Fig.

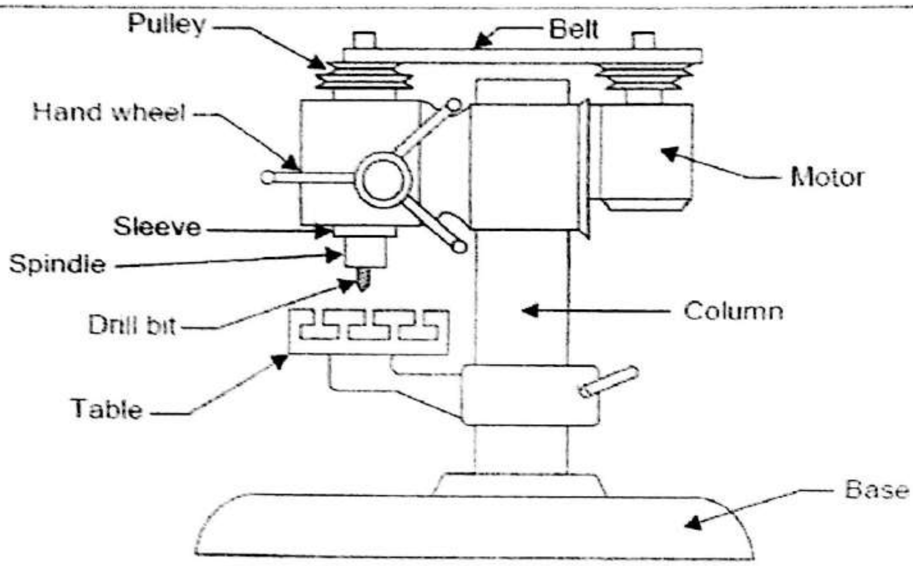


Fig. Drilling Machine.

S.NO	RGPV QUESTIONS	Year	Marks
Q.1	Explain the various drilling operation done by drilling machine.	June 2010	10
Q.2	Discuss any three operations that can perform on a radial drilling machine. Also draw a tabelled diagram of a radial drilling machine.	June 2011	7
Q.3	Explain the working of a vertical drilling machine with the help of a neat sketch. Also state the parameters used to specify a drilling machine.	June 2010	14

Unit - 3
Fluids

Fluids → Fluids is a substance which have ability to flow. The fluid may be -

1.) compressible fluid → which changes volume under pressure. example - air

2.) Incompressible fluid → which does not changes volume under pressure. example - water.

The machine which transforms hydrolic energy into mechanical energy called power producing machine. ex- turbines.
The machine which transforms mechanical energy into hydrolic energy called power consuming machine. ex- hydrolic pump.

Properties of fluid —

1.) Density or mass density → The ratio of mass of the fluid to the volume of the fluid is called density or mass density. Mass occupied by fluid per unit volume is density.

$$\rho = \frac{Mass}{Volume} = kg/m^3$$

2.) Specific weight or weight density → The ratio of weight of the fluid to volume of the fluid is called weight density or specific weight.

$$w = \frac{\text{weight of fluid}}{\text{volume}} = \frac{mg}{v} = \rho \cdot g$$

3.) Specific volume → volume occupied by fluid per unit mass is specific volume.

$$S.V = \frac{\text{volume}}{\text{mass}} = \frac{v}{m} = \frac{1}{\rho}$$

unit → m^3/Kg.

4.) Specific gravity → It is the ratio of density of fluid to the density of standard fluid.

$$S(\text{liquid}) = \frac{\text{Density of fluid}}{\text{Density of water}}.$$

$$S(\text{gas}) = \frac{\text{Density of gas}}{\text{Density of air}}.$$

Que.→ Calculate weight density, density and specific gravity of 1 Litre fluid and 7 Newton weight ?

$1L = 10^{-3} m^3$

$$\text{Specific weight} = \text{weight density} = \frac{\text{Weight}}{\text{Volume}} = \frac{7N}{10^{-3} m^3}$$

$$= 7 \times 10^3 \ N/m^3$$

$$\text{density} = \frac{\text{specific weight}}{g} = \frac{7 \times 10^3}{9.81} = 713.5 \ Kg/m^3$$

$$\text{Specific gravity} = \text{relative density} = \frac{\text{density liquid}}{\text{density water}}$$

$$= \frac{713.5}{1000} = 0.7135$$

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Que.→ calculate density, specific weight and weight of 1L of petrol of specific gravity 0.7.

$S.G = 0.7$,

$V = 1L = 0.001\ m^3$

$$S.G = \frac{\text{density of fluid}}{\text{density of water}}$$

$$0.7 = \frac{\rho}{1000}$$

$$\rho = 0.7 \times 1000$$

$$\rho = 700$$

$$w = \rho \cdot g$$

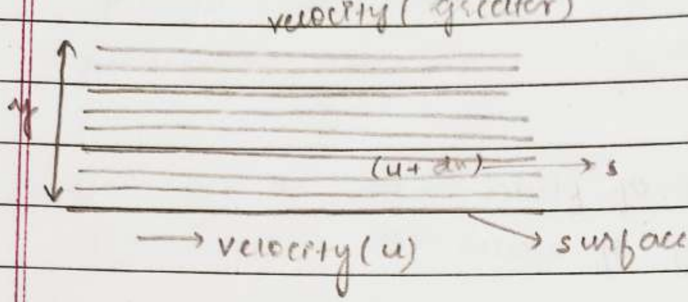
$$w = 700 \times 9.8$$

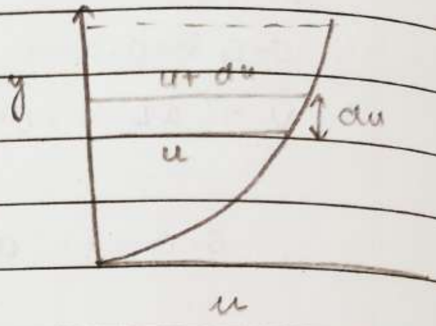
$$w = 68.6 \times 10^2$$

$$S.W = \frac{w}{v} = \frac{68.6 \times 10^2 \times 1000}{0.001 \times 10}$$

Viscosity →

Viscosity is the property of fluid which offers resistance to the movement of one-layer of fluid over another adjacent layer of fluid. When two layers of fluid, a distance dy apart. move one over another at different velocity (u) and (u+du) as shown in figure. The viscosity together with relative velocity causes a shear stress acting between fluid layer.





The shear stress is directly proportional to rate of change of velocity with respect to y.

u → velocity

y → depth

change in velocity → du

velocity greater rate of change = $\frac{du}{dy}$

$$\tau \propto \frac{du}{dy}$$

$$\tau = \mu \frac{du}{dy}$$

$$\boxed{\mu = \tau \frac{dy}{du}}$$

μ → dynamic velocity

unit $\mu = \frac{N\text{-}s}{m^2}$

$$1 \text{ Poise} = \frac{1}{10} \frac{NS}{m^2}$$

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Kinematic viscosity →
Kinematic viscosity is defined as the ratio of dynamic viscosity to the density of fluid.

$$v = \frac{\text{dynamic visocity}}{\text{density of fluid}}$$

$$v = \frac{\mu}{\rho} = \frac{N \times s / m^2}{kg/m} \quad \because f = ma, \quad N = kg \times \frac{m}{s^2}$$

$$v = \frac{m^2}{s}$$

1 Stroke = 10^{-4} m^2/s.

Newton's law of viscosity →
It states that sheared stress on a fluid element is directley proportional to rate of shear strain. The constant of proportionality co-effecient of viscosity.

$$\tau \propto \frac{du}{dy}$$

$$\tau = \mu \frac{du}{dy}$$

μ → coefficient of viscosity.

Ideal fluid — fluid which is incompressible and has viscosity zero or no viscosity is called ideal fluid.

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Real fluid — fluid which has viscosity is called a real fluid.

Que.→ A plate, 0.025 mm distant from a fixed plate, moves at 60 cm/sec and requires a force 2N per unit area i.e, 2N/m² to maintain this speed. Determine the fluid viscosity b/w the plate?

$y = 0.025\ mm = 25 \times 10^{-6}\ m.$

$u = 60\ cm/sec = 60/100\ m/sec$

$\tau = 2\ N/m^2$

$$\tau = \mu \frac{du}{dy} = \frac{2 \times 25 \times 10^{-6} \times 10\not{0}}{6\not{0}}$$

$$\tau = \frac{50 \times 10^{-5}}{6}$$

$$\tau = 8.33 \times 10^{-5}\ Ns/m^2$$

Que.→ A flat plate of area $1.5 \times 10^6\ mm^2$ is pulled with a speed of 0.4 m/sec relative to another plate. find the force required to maintain this speed. consider viscosity of fluid 1 poise. calculate the power also?

$\mu = 1\ poise = \frac{1}{10} \frac{Ns}{m^2}$

$A \rightarrow 1.5 \times 10^6\ mm^2$

$A = 1.5 \times 10^6 \times 10^{-6}\ m^2$

$A = 1.5\ m^2$

$dy = 0.15\ mm$

$= 0.15 \times 10^{-3}\ m$

$u = 0.4\ m/sec$

$$\tau = \mu \frac{du}{dy} = \frac{1}{100} \times \frac{0.4 \times 100}{0.15 \times 10^{-3}} = \frac{4000}{15}$$

$$\tau = 266.6 \ \frac{N}{m^2}$$

$$\tau = \frac{force}{area}$$

$266.6 \times 1.5 = F$

$400 \ N = F$

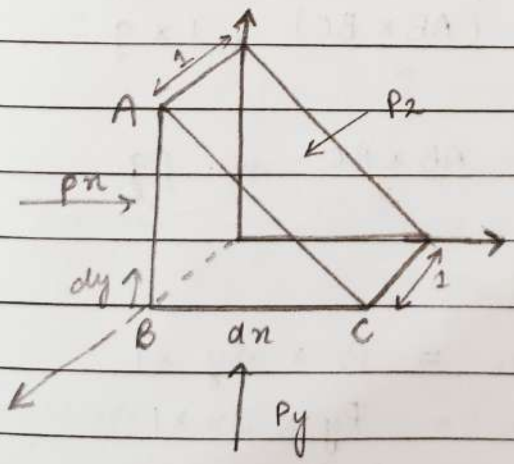
Power $= F \times u$

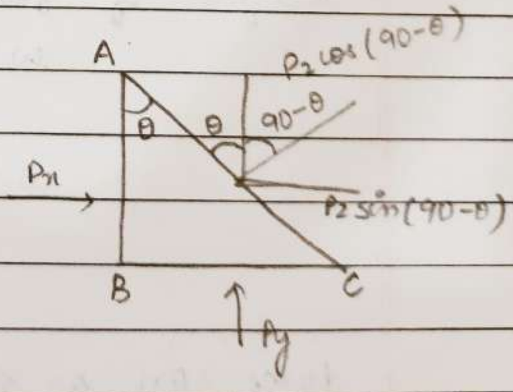
$= 400 \times 0.4$

$= 160 \ W$

Pascals Law ⟶

It states that the pressure or intensity of Pressure at a point in a static fluid is equal in all diraction.





Proof —

$$Pressure = \frac{force}{Area}$$

force = Pressure × Area

force acting on fluid elements -

$$\text{Pressure force} = P_x \times dy \times 1$$

$$y = P_y \times dx \times 1$$

$$z = P_z \times dz \times 1$$

$$\text{weight of fluid} = \rho \times \text{volume} \times g$$

$$w = \rho \times \frac{(AB \times BC)}{2} \times 1 \times g$$

$$W = \rho g \frac{AB \times BC}{2} = \rho g .$$

$$\text{force on } x\text{-direction} = P_z \times dy \times 1$$

$$\text{force on } y\text{-direction} = P_y \times dx \times 1$$

$$\text{force on } T\text{-direction} = P_z \times dz \times 1$$

$$\text{weight of fluid} = \rho \times \text{volume} \times g$$

$$w = \rho \times \frac{(AB \times BC)}{2} \times 1 \times g$$

$$w = \rho g \frac{AB \times BC}{2} = \rho g .$$

$$\text{force on } x\text{-direction} = P_z \times dy \times 1$$

$$\text{force on } y\text{-direction} = P_y \times dx \times 1$$

$$\text{force on } T\text{-direction} = P_z \times dx \times 1$$

$$\text{weight of fluid} = \rho \times \text{Pressure} \times 1 \times g$$

$$= \rho \times \frac{1}{2} (AB + BC) \times g = \rho g \left(\frac{dx . dy}{2} \right)$$

Resolving forces in x- direction

$$P_x * dy \times 1 - P_z \sin(90-\theta)\, dz \times 1 = 0$$

$$p_x \times dy - P_z\, dz \cos\theta = 0$$

$$P_x \times dy = P_z\, dz \times \frac{dy}{dz}$$

$$\boxed{P_x = P_z} \quad \text{--- (1)}$$

Resolving forces in y - direction

$$\Sigma V = 0$$

$$P_y \times dz - P_z\, dz \cos(90-\theta) - \rho g\left(\frac{dx\, dy}{2}\right) = 0$$

$$P_y\, dx - P_z\, dz \sin\theta - \rho g\left(\frac{dx \cdot dy}{2}\right) = 0$$

Weight of fluid neglected due to element is very small.

$$P_y \cdot dx - P_z \cdot dz\, \frac{DC}{AC} = 0$$

$$P_y\, dx = P_z\, dz \times \frac{dx}{dz}$$

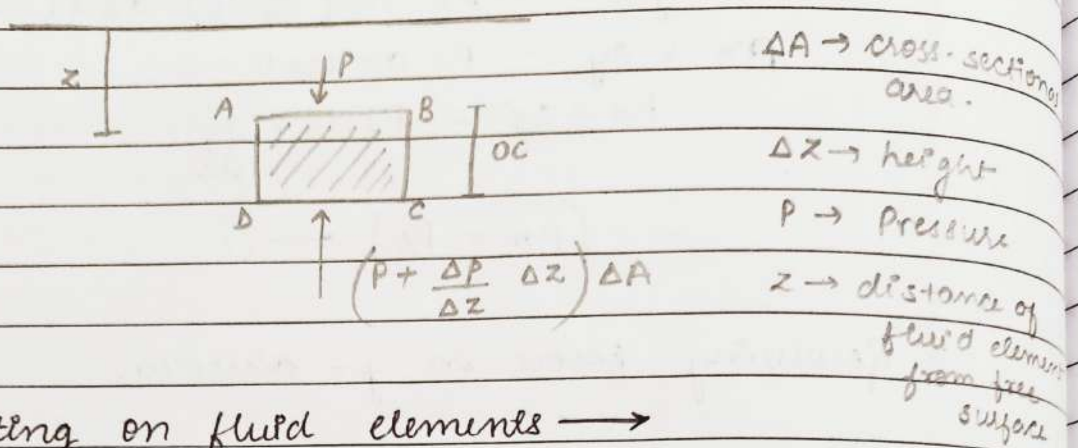
$$\boxed{P_y = P_z} \quad \text{--- (2)}$$

from eq (1) and (2)

$$P_x = P_y = P_z$$

Hydrostatic law of fluids →

Pressure at any point in a fluid at rest is obtained by hydrostatic law which states that the rate of increase of pressure in vertical downward direction must be equal to specific weight of fluid at that point.



Force acting on fluid elements ⟶

1.) Pressure force on AB face = $P\Delta A$.

2.) Pressure force on CD face = $P + \left(\frac{\Delta P}{\Delta Z} \Delta Z\right) \Delta A$

3.) Weight of the element = $\rho \times \Delta A \times L \times g = \rho \Delta A . \Delta z . g$

Equillibrium conditions., $\Sigma V = 0$

$$P\Delta A - \left(P + \frac{\Delta P}{\Delta Z} \Delta Z\right) \Delta A + \rho g \ \Delta A \cdot \Delta Z = 0$$

$$P\Delta A - P\Delta A - \frac{\Delta P}{\Delta Z} \Delta Z \Delta A + \rho g \ \Delta A \ \Delta Z = 0$$

Que. ⟶ A hydrolic press as a RAM of 30 cm diameter and a plunger of 4.5 cm diameter. find the weight lifted by the hydrolic press when the weight applied on plunger is 500 N.

$$\frac{f_{ram}}{A_{ram}} = \frac{f_{plunger}}{A_{plunger}} \quad (\because \text{same pressure intensity})$$

$$f_{ram} = f_{plunger} \times \frac{A_{ram}}{A_{plunger}} = 500 \times \left(\frac{30}{4.5}\right)^2 = 22222.2 \text{ N}$$

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Equation of Motion ⟶

$f = m.a$

f_g — gravitational force
f_p — pressure force
f_v — force due to viscosity
f_T — Turbulance force
f_c — force due to compressibility

$$f_{net} = f_g + f_p + f_v + f_T + f_c$$ — Equation of motion

If fluid is incompressible, $f_c = 0$

$f_{net} = f_g + f_p + f_v + f_T$ (reynolds equation of m.)

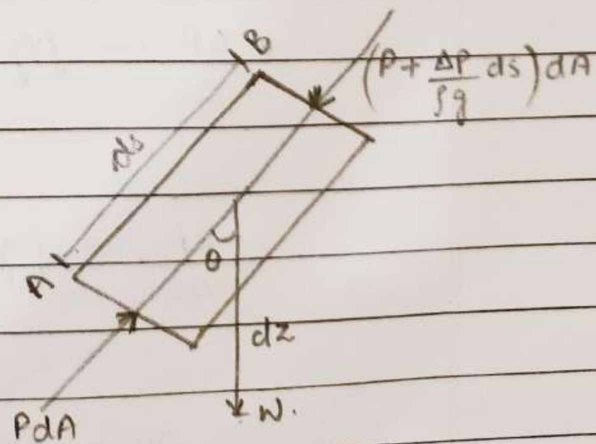
No turbulance, $f_T = 0$

$f_{net} = f_g + f_p + f_v$ (navier's equation of motion)

fluid is ideal, $f_v = 0$

$f_{net} = f_g + f_p$ (Eular's equation of motion)

Eular's equation of motion ⟶



ds — length of pipe
dA — cross sectional area
W — weight of fluid

Pressure force at A side
$= P \times dA$

Pressure force at B side

$$= \left(P + \frac{\Delta P}{\Delta S} ds\right) dA$$

Weight of liquid = w = $\rho g\, dA \cdot ds$

Net force,

$$PdA - \left(P + \frac{\Delta P}{\Delta S} \cdot ds\right) dA - \rho g\, dA \cdot ds \cos\theta .$$

$$PdA - \left(P + \frac{\Delta P}{\Delta S} \cdot ds\right) dA - \rho g\, dA \cdot ds \cos\theta = \rho\, dA \cdot ds \times a$$

$$a = \frac{dv}{dt} = \frac{dv}{ds} \times \frac{ds}{dt}$$

$$a = v \cdot \frac{dv}{ds}$$

$$PdA - PdA - \frac{\Delta P}{\Delta S} \cdot dA \cdot ds - \rho g\, dA \cdot ds \cos\theta = \rho\, dA \cdot ds\, v \cdot \frac{dv}{ds}$$

$$-\frac{\Delta P}{\Delta S} - \rho g \cos\theta = \rho \cdot v \cdot \frac{dv}{ds}$$

$$-\frac{\Delta P}{\Delta S} - \rho g \frac{dz}{ds} = \rho v \cdot \frac{dv}{ds}$$

$$-\Delta p - \rho g\, dz = \rho v\, dv$$

$$\rho v dv + \Delta p + \rho g dz = 0$$

$$\boxed{\frac{v}{g} \cdot dv + \frac{\Delta P}{g\rho} + dz = 0} \quad \text{—— (1) Eular's equation}$$

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Bernoulli's Theorem →

By integrating Euler's Equation

$$\frac{1}{g}\int v\,dv + \int\frac{dp}{\rho g} + \int dz = 0$$

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

$\frac{v^2}{2g}$ — Kinetic energy or head

$\frac{P}{\rho g}$ — Pressure or head

z - Potential energy or head.

Que.→ Water is flowing through a pipe of 5 cm diameter under a pressure of 29.43 N/cm² and with mean velocity of 2 m/s. Find the total head or total energy permit weight of water at a cross-section which is 5m above datum line.

Pressure head = $\frac{P}{\rho g} = \frac{29.43 \times 10^4}{1000 \times 9.81} = 30\,m$

Kinetic head = $\frac{V^2}{2g}$

Datum head = 5m

Total head = $\frac{P}{\rho g} + \frac{V^2}{2g} + z$

$= 30 + 0.204 + 5$

$= 35.204\,m.$

Que. → A pipe through which water flowing, is having diameter 20 cm and 10 cm at the cross sections 1 and 2 respectively. The velocity of water at section 1 is given 4 m/s. find the velocity head at section 1 and 2. Also calculate rate of discharge.

$D_1 = 20\,cm = 0.2\,m \quad D_2 = 10\,cm = 0.1\,m \quad V_1 = 4\,m/s$

$A_1 V_1 = A_2 V_2$

$(\pi/4) \times (D_1)^2 \times V_1 = (\pi/4) \times (D_2)^2 \times V_2$

$\pi/4 \times 0.04 \times 4 = \pi/4 \times 0.01 \times V_2$

$4 \times 0.1256 = 0.0314 \times V_2$

$0.5024 / 0.0314 = V_2$

$V_2 = 16$

Que. → The water is flowing through a pipe having diameter 20 cm and 10 cm at section 1 and 2 resp. The rate of flow through pipe is 35 L/s. The section 1 is 6m above. Detum and section 2 is 4m above detum. If the pressure at section 1 is 39.24 N/cm². find the intensity of pressure section 2

$D_1 = 20cm = 0.2m, \quad A_1 = \pi/4 \times (0.2)^2 = 0.314\,m^2 \quad z_1 = 6.0m$

$P_1 = 39.24\,N/cm^2 = 39.24 \times 10^4\,N/m^2 \quad D_2 = 10cm = 0.1$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \left(\frac{P_2}{\rho g}\right) + \left(\frac{V_2^2}{2g}\right) + z_2$$

$$\left(\frac{39.24 \times 10^4}{1000 \times 9.81}\right) + \left(\frac{1.114^2}{2 \times 9.81}\right) + 6 = \frac{P}{1000 \times 9.81} + \frac{(4.456)^2}{2 \times 9.81} + 4$$

$P_2 = 40.27\,N/cm^2$

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Hydraulic Machines

Hydraulic machines are defined as those machine which converts either hydraulic energy to mechanical energy or mechanical energy to hydraulic energy.

The hydraulic machines which converts hydrollic energy to mechanical are called turbins. while, hydraulic machines which converts mechanical energy to hydrollic energy are called pumps.

Turbins ⟶ Turbins are power producing machine which generate mechanical energ' which is used in running an electric generator directly coupled to the shaft of turbins. for producing electricity.

Classification of hydraulic turbins ⟶

1.) According to energy available at inlet
   a.- Impulse turbine (only kinetic energy)
   b.- Reaction turbine (K.E with pressure energy)

2.) According to direction of flow
   a.- Tengential flow
   b.- Radial flow
   c.- Axial flow
   d.- Mixed flow

3.) According to head at inlet.
   a.- High head turbine
   b.- Medium head turbine
   c.- low head turbine

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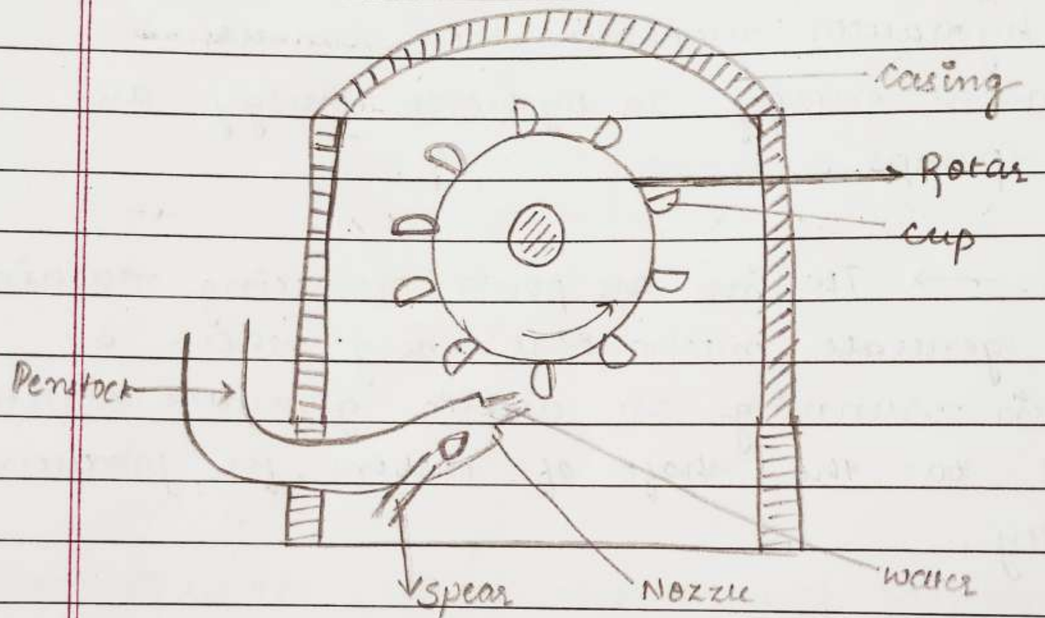
4) According to specific speed.
a.- Low speed
b.- High speed
c.- Medium speed

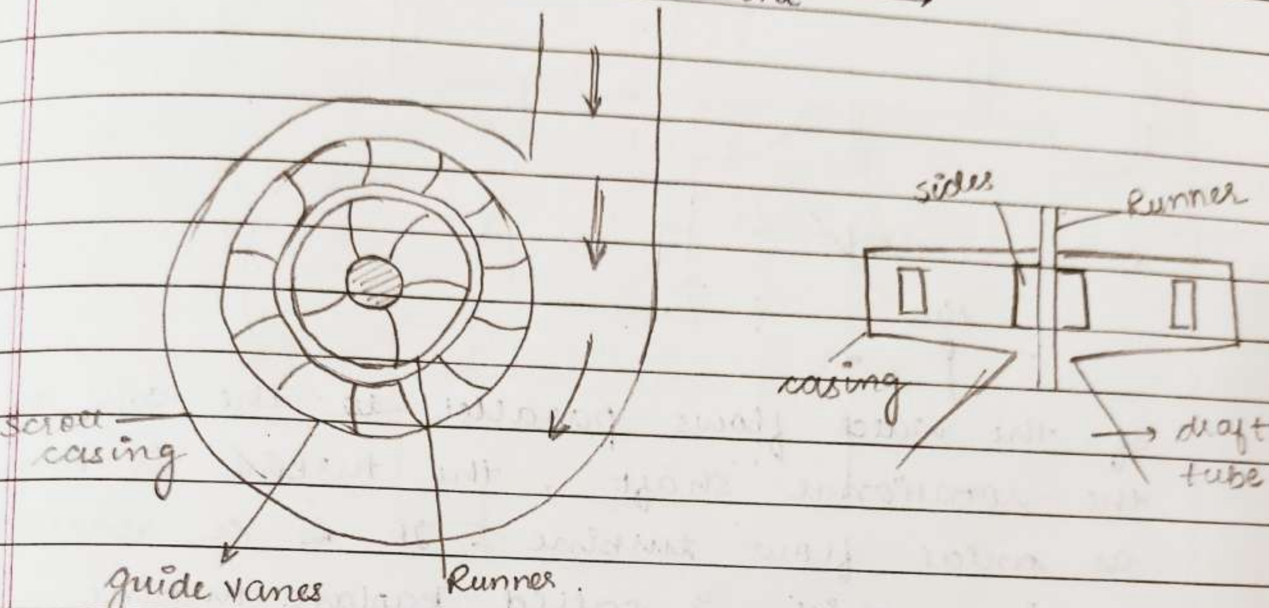
Impulse turbine (Pelton Wheel Turbine) ⟶



The ~~pelt~~ pelton wheel turbine is a tangential flow impulse turbine the water strikes, the bucket along the tangent of the rotal. The energy available at the inlet of the turbine is only the kinetic energy.
figure shows the layout of pelton wheel turbine the water from the resrver flows to the penstock at inlet of which a nozzle is fitted. The nozzle increasses the kinetic energy of water flowing through the penstock. The water from the nozzle strick the bucket of the rotar. and ~~mach~~ mechinical energy produced at

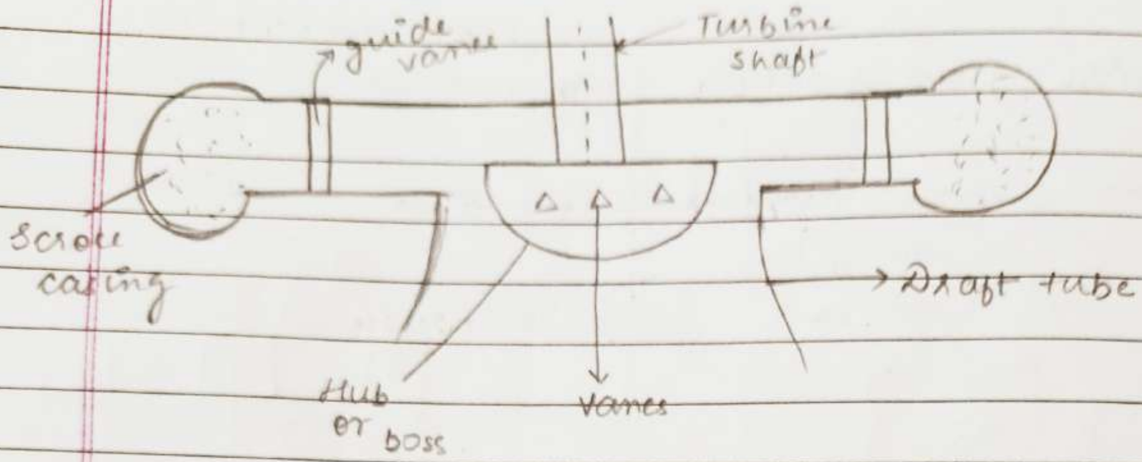
the turbine shaft.

Radial flow reaction turbine →



Radial flow turbines are those turbines in which the water flows in the radial direction. Water maybe flow radially from outward to inward or inward to outward.
Radial turbins means both kinectic energy and pressure energy available at the inlet. as the water flows to the runner, a part of pressure energy converted to kinetic energy. Thus, the water to runner is under pressure, the runner is completely enclosed in an air tight casing and this casing is always full of water.

Axial flow turbine (Kaplan turbine) ⟶



If the water flows parallel to the axis of the rotational shaft , the turbine is known as axial flow turbine . It is a reaction turbine which is called kaplan turbine .
for the axial flow reaction turbine the shaft of the turbine is vertical the lower portion of the shaft is made larger which is known as hub or boss . The vanes are fixed on the hub and hence hub act as runner .
figure shows the main parts of ~~ca~~ Kaplan turbine in which blades are adjustable according to required speed . The water from penstock enter the scroll casing and then moves to the guide vanes . from the guide vanes the water turns through 90° and flows axially through the runner , where mechanical energy produced on the turbine shaft .

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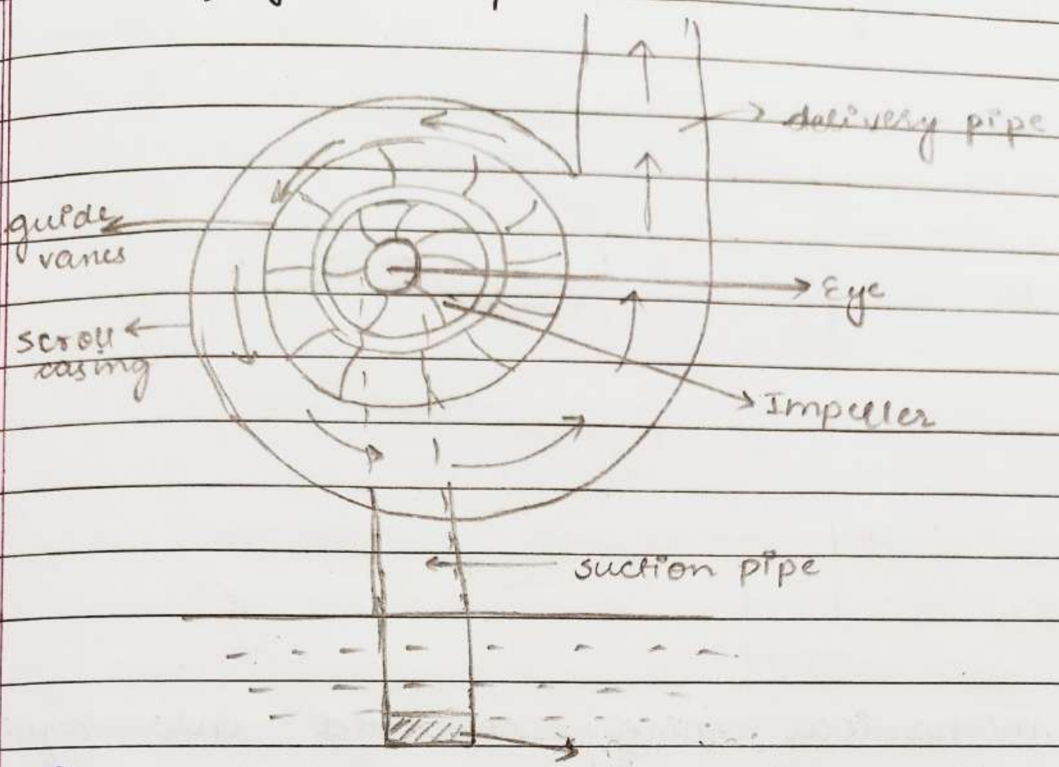
Centrifugal Pump →



A centrifugal pump works on the principle that 'when a certain mass of fluid is rotated by external source, it is thrown away from the central axis of rotation and a centrifugal head is impressed which enables it to rise to higher level.

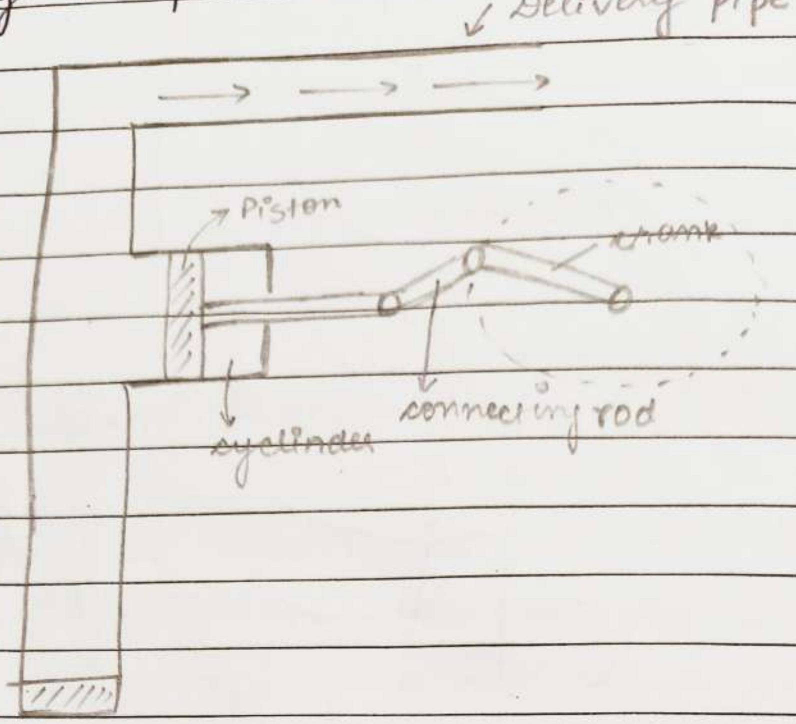
Construction and working →

i) impeller → The rotating part of centrifugal pump is impeller. It is mounted on shaft.

ii) Casing → It is air tight passage surrounding the impeller and is designed in such way that kinetic energy is converted into pressure energy

iii) Suction pipe → It is a pipe whose one end is connected to inlet of the pump and other end dips into water in a sump.

Reciprocating Pump →



If mechanical energy converted into hydraulic energy by sucking liquid into cyclinder in which a piston is reciprocating which exerts the thrust on the liquid and increases the hydraulic energy, the pump is known as reciprocating pump.

Working and construction

i) connecting rod and crank → crank is connected to piston by connecting rod thus converting rotatry motion of crank into reciprocating motion

ii) Piston and cyclinder → The piston reciprocates inside cyclinder. Connecting rod is connected to piston by piston pin.

iii) Suction pipe → It is the pipe which is connected to suction of the pump, through this pipe, the liquid will be sucked from sump.

iv) Sump → It is the reservoir of liquid through which water will be pumped.

Unit - 4

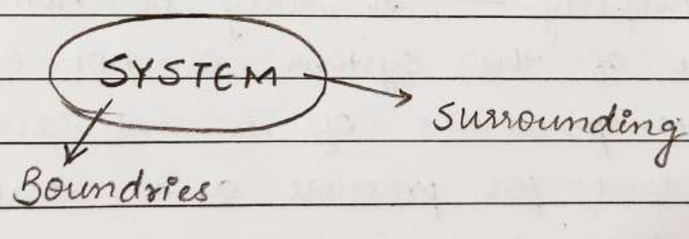
Thermodynamics

Introduction →

It is the field of science which deal with the energies possessed by air and vapour. It is also deals with the conversion of heat energy into mechanical energy or vise - versa. The machine which transforms heat energy into mechanical work is called heat engin. The machine which transfoms mechanical work into heat energy are called refrigerator and air conditioner.

Thermodynamic System →

A thermodynamic system may be defened as a definite region or area where some thermodynamic processes takes place.



Open System → both heat & mass transfer occured.

Closed system → only heat transfer takes place.

Isolated System → no heat and mass transfer.

State of System →

A state of system is the condition of system at any particular moment which can be identified by the statements of its properties such as pressure, volume, temperature, etc.

Thermodynamic Process →

When the system changes its state from one equilibrium state to another equilibrium state, then the path of successive state through which the system has passed is known as thermodynamic process.

Thermodynamic Properties →

1) Extensive property — quantity of matter in a given system is divided into numbers of parts, the properties of the system whose value for the entire system is equal to the sum of their value for the individual part of the system is called entensive properties.

2) Intensive property — It may be noticed that the temperature of the system is not equal to the sum of temperatures of its individual part. It is also true for pressure and density of the system. Thus properties like temperature, pressure density etc is called intensive properties.

Thermodynamic Equilibrium →

1) Mechanical Equilibrium — No unbalance force

2) Thermal Equilibrium - No heat transfer.

3) Chemical Equilibrium — NO chemical reaction.

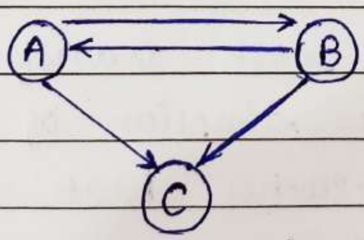
Laws of Thermodynamics ⟶

1.) Zeroth law of thermodynamics —
law of thermal equilibrium.

2.) first law of thermodynamics —
law of conservation of energy

3.) Second law of thermodynamics

Zeroth law of thermodynamics ⟶
It states that when two system are each in thermal equilibrium with a third system, then the two systems are also in thermal equilibrium with each other.
This law is used in temperature measurement



When, $T_1 = T_3$
$T_2 = T_3$
then, $T_1 = T_2$.

first law of Thermodynamics ⟶
Heat and work are mutually convertible —
according to this statement when a close system undergoes a thermodynamic cycle.

The net heat transfer is equal to net work transfer. In other words, integral heat transfer is equal to integral of work transfer

$$\oint \delta Q = \oint \delta W$$

Energy can neither be created nor be destroyed it can only change from one form to another form —

According to this statement when a system goes a thermodynamics process then both heat transfer and work transfer takes place. The net energy transfer within the system is stored and it is known as stored energy and total energy of the system.

stored energy ← $E = \delta Q - \delta W$ → work energy
(δQ ↓ heat energy)

Limitations of first law of thermodynamics →

1.) When a thermodynamic system undergoes thermodynamic cycle. The net heat transfer is equal to net work transfer. This statement does not specify the direction of flow of heat and work. i.e, whether heat is flowing hot body to cold body or cold body to heat body.

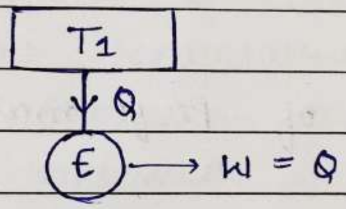
2.) Through the Mechanical work can be fully converted into the heat energy but only a part of heat energy is converted into mechanical work. This means heat and work are not fully mutually convertible.

Second law of thermodynamics ⟶

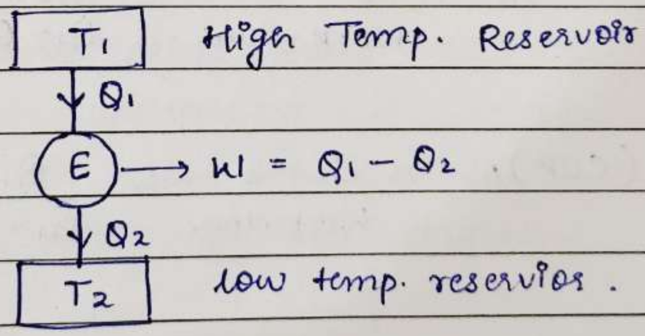
1.) Kelvin Plack Statement —

According to kelvin Plank it is impossible to construct a heat engine working on thermodynamic cycle, whose sole purpose is to convert heat energy from a single thermal resovEir.

Impossible



Practical



$$\eta_{max} = \frac{\text{work done}}{\text{heat supplied}} = \frac{Q_1 - Q_2}{Q_1}$$

$$\eta_{max} = 1 - \frac{Q_2}{Q_1}$$

$$\eta_{max} = 1 - \frac{T_2}{T_1}$$

mechanical work. This means heat and work are not fully mutually convertible.

Second law of thermodynamics ⟶

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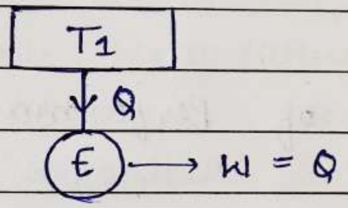
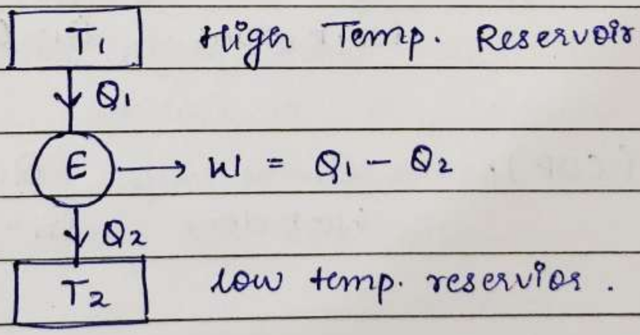


Practical



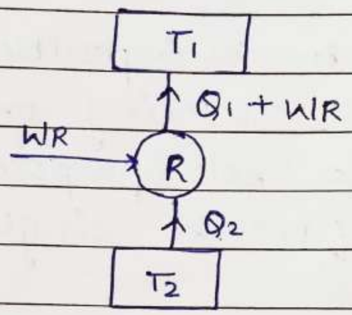
$$\eta_{max} = \frac{\text{Work done}}{\text{heat supplied}} = \frac{Q_1 - Q_2}{Q_1}$$

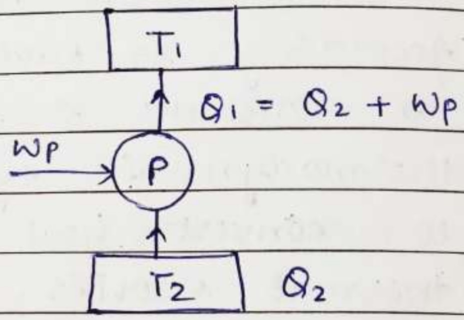
$$\eta_{max} = 1 - \frac{Q_2}{Q_1}$$

$$\eta_{max} = 1 - \frac{T_2}{T_1}$$

2.) Clausius Statement —

According to clausis statement it is impossible to construct a refrigerator or heat pump working in a cyclic process to transfer heat from a lower body temperature without any external work.





Coefficient of Performance

$$(COP)_R = \frac{Q_2}{\text{Work done}} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$$

$$(COP)_P = \frac{Q_1}{\text{Work done}} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$$

Que.→ An engine works between the temperature limits of 1775 Kelvin and 375 Kelvin. What can be the maximum efficiency of the engine.

$T_1 = 1775 K$

$T_2 = 375 K$

$\eta_{max} = ?$

$$\eta_{max} = 1 - \frac{T_2}{T_1} = 1 -$$

$$\eta_{max} = 1 - \frac{375}{1175}$$

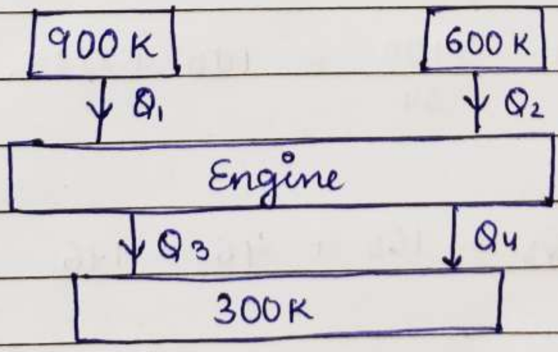
$$\eta_{max} = \frac{71 - 11}{71} = \frac{60}{71}$$

$$\eta_{max} = 0.78$$

Que.→ A reversible engine is supplied with heat for two constant temperature sources at 900 Kelvin and 600 Kelvin and rejects heat to a constant temperature sink to 300 Kelvin. The engine develope work equivalent to 90 kilo joule/second and reject heat at the rank of 56 kJ/s. Estimate —

i) heat supply by each ~~other~~ source.

ii) Thermal efficiency of the engine.



Equilant work = $w_1 + w_2$ = 90 KJ/sec

heat rejected = $Q_2 + Q_4$ = 56 KJ/sec

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heat supplied by each source $Q_1 = ?$; $Q_3 - ?$

Thermal efficiency = $\frac{\text{workdone}}{\text{heat supplied}}$

$\eta_1 = 1 - \frac{300}{900} = 0.67$, $\eta_2 = 1 - \frac{300}{600} = 0.5$

$\eta_1 = \frac{W_1}{Q_1}$ $\eta_2 = \frac{W_2}{Q_2}$

$W_1 = \eta_1 Q_1 = 0.67 Q_1$ $W_2 = 0.5 Q_3$

$0.67 Q_1 = Q_1 - Q_2$ $W_2 = Q_3 - Q_4$

$-Q_2 = 0.33 Q_1$ $0.5 Q_3 = Q_3 - Q_4$

$Q_2 = 0.33 Q_1$ $Q_4 = 0.5 Q_3$

$Q_1 = 100$ KJ/sec

i) $0.67 Q_1 + 0.5 Q_3 = 90$

$0.67 \times 100 + 0.5 Q_3 = 90$

$Q_3 = 46$ KJ/sec

$0.34 Q_1 = 34$

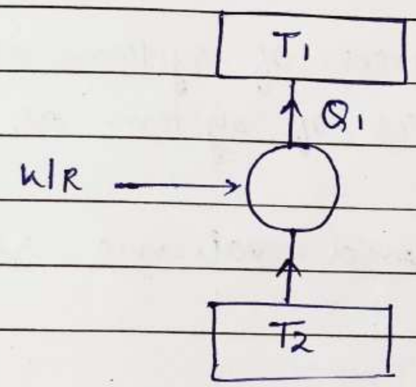
$Q_1 = \frac{3400}{34} = 100$ KJ/sec

ii) Total = $Q_1 + Q_3 = 100 + 46 = 146$

Thermal efficiency = $\frac{\text{workdone}}{\text{heat supplied}} = \frac{90}{146}$

$= 0.62$

Que. → A cold storage is to be maintained at -5°C while the sorrounding are at 35°C. The heat leakage from the sorrounding into the cold storage is estimated to be 29 Kilo wat. The actual C.O.P of the plant is 1/3 of an ideal plant working between the same temperature. find the power (work) required to drive the plant.



$T_2 = -5°C = -5 + 273 = 268\ K$

$T_1 = 35°C = 35 + 273 = 308\ K$

$$(C.O.P)\ ideal = \frac{T_2}{T_1 - T_2} = \frac{268}{308 - 268} = 6.7$$

$$(C.O.P)\ actual = \frac{1}{3} \cdot (COP)\ ideal$$

$$= \frac{1}{3} \times 6.7$$

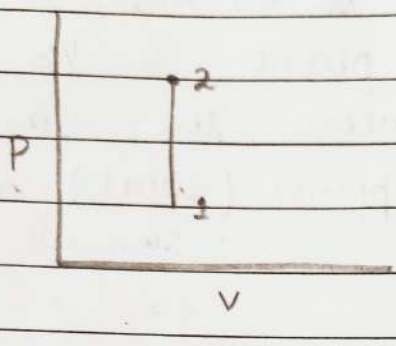
$$= 2.23$$

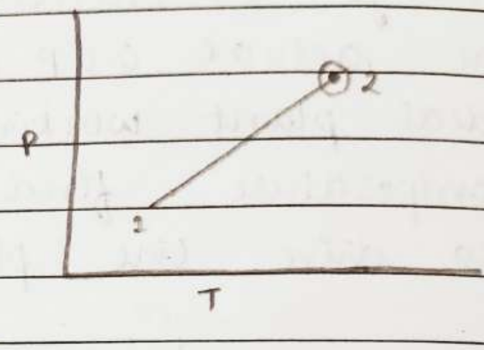
$$C.O.P = \frac{heat}{workdone}$$

$$workdone = \frac{heat}{C.O.P} = \frac{29}{2.23} = 13.004\ K.W$$

Thermodynamic Process →

1.) Constant Volume Process (Isochoric Process)





$P_1 V_1$ and T_1 = properties of system at state 1.
$P_2 V_2$ and T_2 = properties of system at state 2.

i) Pressure, Temperature and Volume relationship

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \{ V_1 = V_2 \}$$

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

ii) Workdone

$$W_{1-2} = PV$$

$$W_{1-2} = \int_1^2 PV = P(V_2 - V_1)$$

$$W_{1-2} = 0 \quad \{ V_2 = V_1 \}$$

$K = C + 273^\circ$

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iii) change in internal energy

$$du = m C_v \Delta T$$

$$V_2 - V_1 = m C_v (T_2 - T_1)$$

iv.) Heat Supplied

$$\delta Q = du + \delta w.$$

$$Q_{1-2} = m\ C_v (T_2 - T_1) + 0$$

$$Q_{1-2} = m\ C_v (T_2 - T_1)$$

$CP = 1.005\ KJ/Kg \cdot K$

$Cv = 0.712\ KJ/Kg \cdot K$

$R = 287\ J/Kg \cdot R$

v.) Change in enthalpy

$$dH = du + d(PV)$$

$$H_2 - H_1 = V_2 - V_1 + (P_2V_2 - P_1V_1)$$

$$= mC_v(T_2 - T_1) + (mRT_2 - mRT_1)$$

$$= mC_v(T_2 - T_1) + mR(T_2 - T_1)$$

$$= m(T_2 - T_1)(C_v + R)$$

$$= m(T_2 - T_1)(C_v + C_p - C_v)$$

$$= m\ C_p (T_2 - T_1)$$

Que. → A certain gas occupies $0.3\ m^3$ space at a pressure of 2 bar and a temperature of 77°C. It is heated at a constant volume until the pressure 7 bar. Determine —

i) Temp. at end of the process.

ii) Mass of gas

iii) change in internal energy

iv.) change in Enthalpy during process.

Assume — $C_p = 1.005\ KJ/Kg \cdot K$

$C_v = 0.712\ KJ/Kg\ K$

$R = 287\ J/Kg\ R.$

i) $\frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow \frac{2 \times 10^5}{7 \times 10^5} = \frac{350}{T_2}$

$T_2 = \frac{350 \times 7}{2} = 1225\ K.$

ii) $P_1 V_1 = m R T_1$

$m = \frac{P_1 V_1}{R T_1} = \frac{2 \times 10^5 \times 0.3}{287 \times 350}$

$m = 0.597\ kg = 0.60\ kg.$

iii) $U_2 - U_1 = m C_v (T_2 - T_1)$

$= 0.60 \times 0.712 (1225 - 350)$

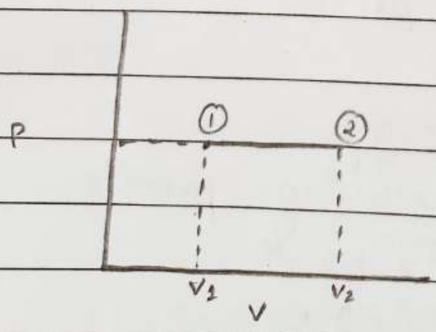
$= 371.93\ KJ$

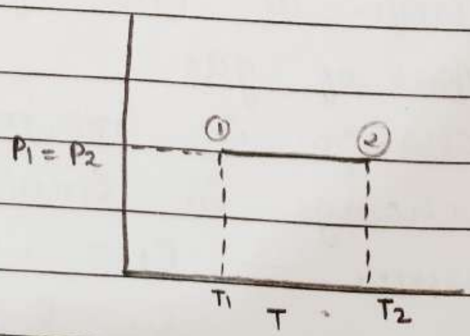
iv.) $H_2 - H_1 = m C_p (T_2 - T_1)$

$= 0.59 \times 1.005 (1225 - 350)$

$= 527.625\ KJ.$

2.) Constant Pressure Process





$P_1 V_1$ and T_1 = properties of system at state 1

$P_2 V_2$ and T_2 = properties of system at state 2

i) Pressure, volume, Temperature relationship

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$\{P_1 = P_2\}$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

ii) change in internal energy

$du = U_2 - U_1 = mC_v(T_2 - T_1)$

iii) Workdone

$\delta W = P\,dv$

$W_{1-2} = P(V_2 - V_1)$

$\{PV = mRT\}$

$W_{1-2} = mR(T_2 - T_1)$

iv.) Heat supplied

$\delta Q = du + dw$

$Q_{1-2} = mC_v(T_2 - T_1) + mR(T_2 - T_1)$

$= m(T_2 - T_1)(C_v + R)$

$= mC_p(T_2 - T_1)$ $\{R = C_p - C_v\}$.

v.) change in enthalpy

$H_2 - H_1 = mC_p(T_2 - T_1)$

Que. → The values of specific heat at constant pressure and at constant volume for an ideal gas are 0.984 Kg J/ Kg.K and 0.728 KJ/Kg K.

Date

find the values of characteristic gas constant and ratio of specific heat for the gas. If ~~or~~ 1 kg of gas is heated at constant pressure from 25°C to 200°C. Estimate heat added, work done, change in internal energy and pressure and final volume if the initial volume is $2 m^3$.

$T_1 = 25°C = 25 + 273 K = 298 K$

$T_2 = 200°C = 200 + 273 K = 473 K$

$C_p = 0.984 \quad C_v = 0.728$

$m = 1 kg.$

$R = C_p - C_v = 0.984 - 0.728 = 0.256 \ KJ/kg.K$

ratio of specific heat $= \frac{C_p}{C_v} = \frac{0.984}{0.728} = 1.35$

Heat added $= m \cdot C_p (T_2 - T_1)$

$= 1 \times 0.984 (473 - 298)$

$= 0.984 \times 175$

$= 172.2 \ KJ$

Work done $= mR (T_2 - T_1)$

$= 1 \times 0.256 (473 - 298)$

$= 0.256 \times 175 = 44.8 \ KJ$

change in internal energy $= m C_v (T_2 - T_1)$

$= 1 \times 0.728 \times 175$

$= 127.4 \ KJ$

Pressure = $P_1 V_1 = mRT_1$

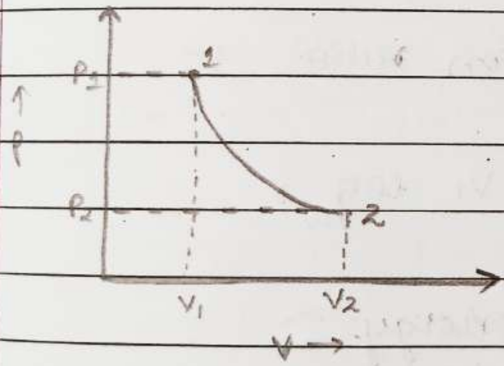
$$P_1 = \frac{mRT_1}{V_1} = \frac{1 \times 0.256 \times 298}{2}$$

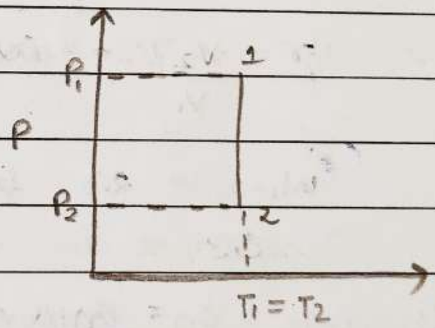
$P_1 = 38.144$

volume = $\frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow V_2 = \frac{V_1 \times T_2}{T_1}$

$$V_2 = \frac{2 \times 473}{298} = 3.14\ m^3$$

3) Constant temperature Process





$P_1 V_1$ and T_1 = properties of gas at state 1.
$P_2 V_2$ and T_2 = properties of gas at state 2.

i) Pressure, Temp. and volume relationship

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$T_1 = T_2$

$P_1 V_1 = P_2 V_2$ constant

$$\frac{P_1}{P_2} = \frac{V_2}{V_1}$$

ii) Workdone

$$\delta W = P.dv$$

$$\int_1^2 \delta W = \int_1^2 P.dv$$

$$PV = P_1V_1$$

$$P = \frac{P_1V_1}{V}$$

Putting the value of P in eq (1)

$$\int_1^2 \delta W = \int_1^2 \frac{P_1V_1}{V} . dv$$

$$W_{1-2} = P_1V_1 \log_e [V]_1^2$$

$$W_{1-2} = P_1V_1 \log_e \left(\frac{V_2}{V_1}\right) = 2.3\ P_1V_1 \log_{10}\left(\frac{V_2}{V_1}\right)$$

$$r = \frac{V_2}{V_1} = \text{Expansion ratio}$$

$$W_{1-2} = 2.3\ ~~\log~~\ P_1V_1 \log_{10} r$$

iii) change in internal energy

$$U_2 - U_1 = mC_v(T_2 - T_1)$$

$$U_2 - U_1 = 0 \qquad \{T_1 = T_2\}$$

iv.) Change in enthalpy

$$H_2 - H_1 = mC_p(T_2 - T_1)$$

$$H_2 - H_1 = 0 \qquad \{T_1 = T_2\}$$

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Que.→ A quantity of air has a volume of $0.4 m^3$ at a pressure of 5 bar and a temperature of 80°C it is expanded in a cylinder at a constant temperature to a pressure of 1 bar. Determine the amount of workdone during the expansion.

$P_1 = 5$ bar $\quad P_2 = 1$ bar $\quad V_1 = 0.4\ m^3$

$T = 80°C = 80 + 273 = 353\ K$

$$\frac{P_1}{P_2} = \frac{V_2}{V_1} \qquad \frac{5}{1} = \frac{V_2}{0.4}$$

$$V_2 = 2\ m^3$$

$$r = \frac{V_2}{V_1} = \frac{2}{0.4} = 5$$

$$W = 2.3 \times 5 \times 0.4 \times \log_{10} 5$$

$$W = 2.3 \times 5 \times 0.4 \times 0.69 \times 10^5$$

$$W = 3.174 \times 10^5$$

Que.→ $0.1 m^3$ of air at a pressure of 1.5 bar is expanded isothermaly to $0.5 m^3$ calculate the final pressure of the gas and heat supplied during the process.

$V = 0.1 m^3 \quad P_1 = 1.5$ bar $= 1.5 \times 10^5\ N/m^2$

$V_2 = 0.5 m^3$

$$\frac{P_1}{P_2} = \frac{V_2}{V_1} \qquad \frac{1.5 \times 10^5}{P_2} = \frac{0.5}{0.1}$$

$$P_2 = \frac{1.5 \times 10^5}{\ } = 0.3 \times 10^5$$

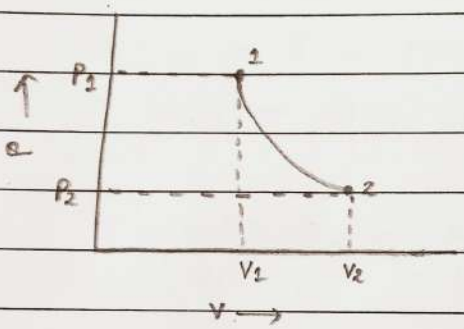
$$\gamma = \frac{V_2}{V_1} = \frac{0.5}{0.1} = 5$$

$$W = 2.3 \; P_1 V_1 \log_{10} \gamma$$

$$W = 2.3 \times 1.5 \times 10^5 \times 0.1 \times 0.69$$

$$W = 0.238 \times 10^5$$

4.) Adiabatic Process (Isentripic process)



$$\delta Q = 0$$

$$PV^{\gamma} = \text{constant}$$

$$\gamma = \text{Ratio of specific heat } \frac{C_1}{C_2}$$

i) Pressure, volume and temperature relationship

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$\left(\frac{P_1}{P_2}\right) = \left(\frac{V_2}{V_1}\right)^{\gamma}$$

we know that,

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{P_1}{P_2} = \frac{V_2}{V_1} \times \frac{T_1}{T_2}$$

Putting the value in eq ①

$$\frac{V_2}{V_1} \times \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma} \quad — ②$$

We know that

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{V_2}{V_1} = \frac{P_1}{P_2} \times \frac{T_2}{T_1}$$

Putting this value in eq ②

$$\frac{P_1}{P_2} \times \frac{T_2}{T_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma}$$

$$\frac{T_2}{T_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma - 1}$$

$$\frac{T_2}{T_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1-\gamma}{\gamma}}$$

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$$

ii) Workdone

$$\delta W = P.dv$$

$PV^{\gamma} = P_1 V_1^{\gamma}$ · ~~V^{γ}~~

$$P = \frac{P_1 V_1^{\gamma}}{V^{\gamma}}$$

$$\delta W = \frac{P_1 V_1^{\gamma}}{V^{\gamma}} . dv$$

$$\int \delta W = \int \frac{P_1 V_1^{\gamma}}{V^{\gamma}} . dv$$

$$W_{1-2} = P_1 V_1^{\gamma} . \int \frac{1}{V^{\gamma}} . dv$$

$$W_{1-2} = P_1 V_1^{\gamma} \left[V^{-\gamma+1} \right]^2$$

$$W_{1-2} = \frac{P_1 V_1^{\gamma}}{-\gamma+1} \left[V_2^{-\gamma+1} - V_1^{-\gamma+1} \right]$$

$$W_{1-2} = \left[\frac{P_1 V_1^{\gamma} \quad V_2^{-\gamma+1} \quad P_1 V_1^{\gamma} \quad V_1^{-\gamma+1}}{1-\gamma} \right]$$

$$W_{1-2} = \frac{P_2 V_2 - P_1 V_1}{1-\gamma}$$

$$\boxed{W_{1-2} = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}}$$ — Expension process.

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$$W_{2-1} = \frac{P_2 V_2 - P_1 V_1}{\gamma - 1}$$ — compression

iii) change in internal energy

$$U_2 - U_1 = mC_v (T_2 - T_1)$$

iv.) Heat supplied

$$\delta Q = 0$$

v.) change in enthalpy

$$H_2 - H_1 = mC_p (T_2 - T_1)$$

Que.→ The initial volume of 0.18 kg of a certain gas was 0.15 m^3 at a temperature of 15°C and a pressure of 1 bar. After adiabatic compression to 0.056 m^3 the pressure was found 4 bar.
find — i) gas constant ii) molecular mass of gas
iii) ratio of specific heat iv.) two specific heat
v.) change of internal energy.

i) $P_1 V_1 = mRT_1$

$$1 \times 0.15 = 0.18 \times R \times 288$$

$$R = \frac{0.15}{51.84} = 0.002894 = 289.4 \times 10^5$$

ii) $$m = \frac{R_u}{R} = \frac{8314}{289.4 \times 10^5} = 28.7 \text{ kg}$$

iii) $$\gamma = \frac{\log(P_1/P_2)}{\log\left(\frac{V_2}{V_1}\right)} = \frac{\log(1/4)}{\log\left(\frac{0.056}{0.15}\right)} = \frac{\log 0.25}{\log 0.37}$$

$$\gamma = \frac{0.5}{0.60} = 0.83$$

iv.) $C_p - C_v = R$

$$\frac{C_p}{C_v} = \gamma$$

$$\frac{C_p}{C_v} = 1.407$$

$$C_p = 1.407\, C_v$$

$$1.407\, C_v - C_v = 289.4$$

$$0.407\, C_v = 289.4$$

$$C_v = \frac{289.4}{0.407} = 722.$$

$$C_p = 1.407 \times 0.722 = 1\ KJ/kg\,K.$$

v.) $u_2 - u_1 = mC_v\,(T_2 - T_1)$

$$= 0.18 \times 0.722\,(T_2 - 288)$$

$$\frac{T_2}{T_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1-\gamma}{\gamma}}$$

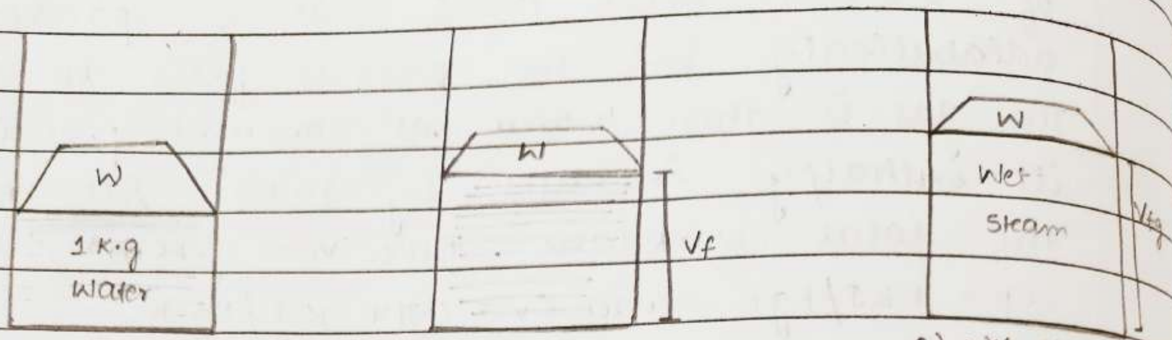
$$T_2 = \left(\frac{1}{4}\right)^{\frac{1-1.407}{1.407}} \times 288$$

$$T_2 = 4308\ K$$

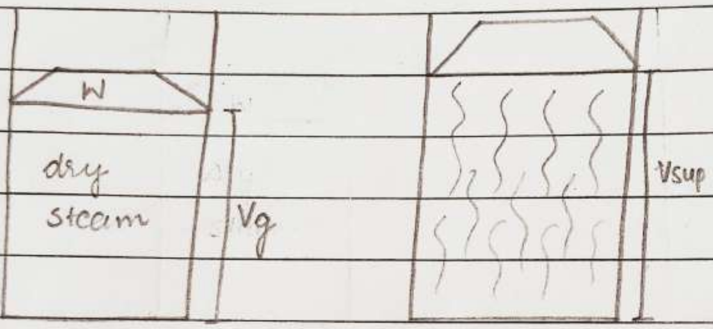
$$u_2 - u_1 = 0.18 \times 0.722\,(4308 - 288)$$

$$u_2 - u_1 = 18.2\ J$$

Steam foundation →



a.) Room Temp. b.) Boiling point (100°c) c.) Wet steam



d.) dry steam e.) Super heated steam

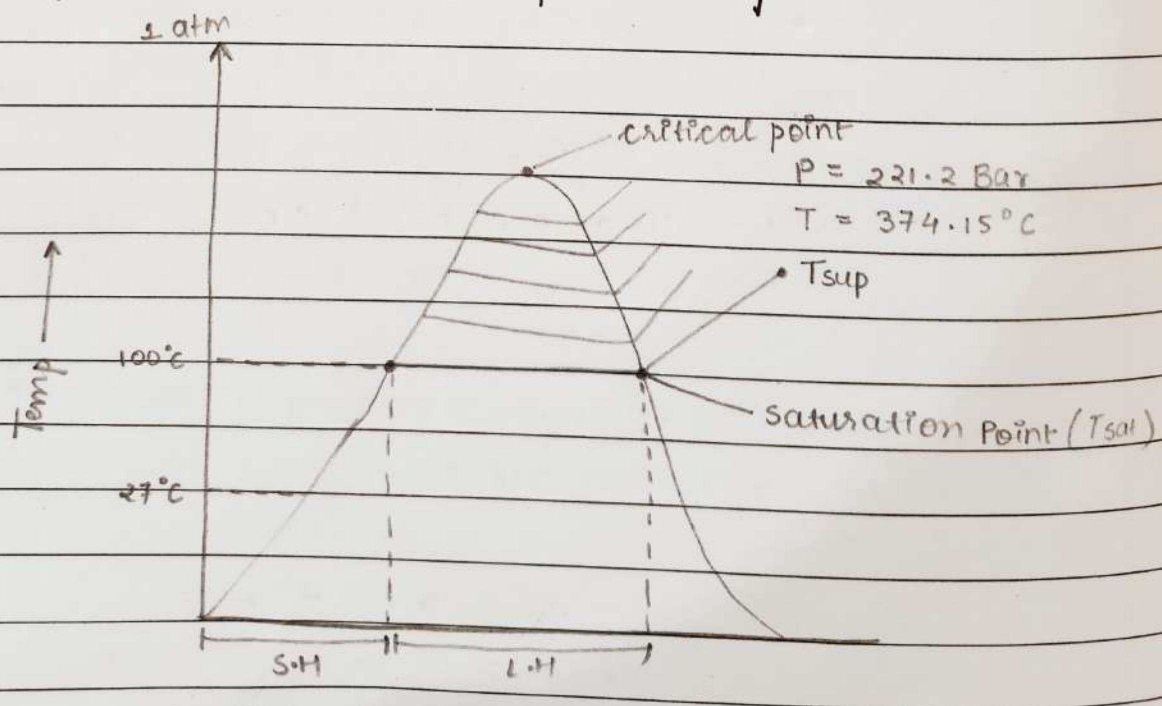
V_f → specific volume of water

V_{fg} → spec. vol. of wet steam

V_g → spec. vol. of dry steam

V_{sup} → specific volume of super heated steam

Temperature V/s heat Relationship →



S.H → sensible heat of water

L.H → latent heat of vaporization.

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Enthalpy of steam →

1.) Wet steam

enthalpy $= h = h_f + x h_{fg}$

2.) Dry steam

enthalpy $= h = h_f + h_{fg}$

3.) Super heated steam

enthalpy $= h = h_f + h_{fg} + C_p(T_{sup} - T_{sat})$

where, C_p – mean specific heat of steam

T_{sup} – superheated Temperature

T_{sat} – Saturated Temperature.

Que.→ calculate the enthalpy of 1 Kg of steam at a pressure 8 Bar and dryness fraction 0.8. How much the heat require to raise 2 K.g of this steam from water at 20°C.

$P = 8$ Bar

$x = 0.8$

$t = 20°C = 20 + 273 = 293 K$

at 8 Bar

$h_f = 721.3$ KJ/Kg

$h_{fg} = 2046.5$ KJ/Kg

Total enthalpy $h = h_f + x h_{fg} - 4.2 \times 20$

$h = 721.3 + 0.8 \times 2046.5 - 84$

$h = 2274.5$ KJ/Kg

enthalpy of 2 kg steam = 2 × 2274.5

= 4549 KJ.

Que. → Determine the quantity of heat required to produce 1 kg of steam at a pressure of 6 Bar and at a temperature of 25°C under the following conditions —

i) When the steam is wet having a dry fraction of 0.9

ii) When steam is dry saturated

iii) When it is super heated at a constant pressure to 250°C. Assume the mean specific heat of steam is 2.3 KJ/kg K.

$P = 6$ Bar

At 6 Bar,

$h_f = 670.8$ KJ/kg. $C_p = 2.3$

$h_{fg} = 2085$ KJ/kg $T_{sup} = 250°C = 250+273$

$T = 158.87$ $= 523$ K.

i) When steam is wet

$x = 0.9$

$h = h_f + x h_{fg} - 4.2 \times 25$

$h = 670.8 + 0.9 \times 2085 - 105$

$h = 2442.3$ KJ/kg.

ii) When dry steam

$h = h_f + h_{fg} - 4.2 \times 25$

$h = 670.8 + 208.5 - 105$

$h = 2650$ KJ/kg

iii) Superheated

$= h_f + h_{fg} + C_p (T_{sup} - T_{sat}) - 4.2 \times 25$

$= 670.8 + 2085 + 2.3(523 - 158.87)$

$= 2755 + 2.3 \ (364.13)$

$= 3487.499$ KJ

Internal Energy of steam ⟶

$du = \delta Q - \delta w$

$d\epsilon = h - Pdv$

$d\epsilon = h - P(v_2 - v_1)$

$d\epsilon = h - P(v_g - v_f)$

$$\boxed{u = h - Pv_g}$$

$= h - 10^5 P \times v_g$

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$$\boxed{u = h - 100 \ Pv_g.}$$

1.) Wet steam,

$u = h_f + x h_{fg} - 100 \ P \times x v_g$

2.) Dry steam

$u = h_f + h_{fg} - 100 \ Pv_g$

3.) Superheated steam

$u = h_f + h_{fg} + C_p (T_{sup} - T_{sat}) - 100 \ Pv_g$

Que. → calculate the internal energy of 1 kg of steam at a pressure of 10 Bar. When the steam is —

i) 0.9 dryness fraction

ii) Dry saturated.

$P = 10$ Bar

$h_f = 763.0$ KJ/kg

$h_{fg} = 2013.5$ KJ/kg

$T_{sat} = 179.97$

$V_g = 0.1933$

$$U = h_f + x h_{fg} - 100 P \times x V_{fg}.$$

$$= 763.0 + 0.9 \times 2013.5 - 100 \times 10 \times 0.9 \times 0.1933$$

$$= 2575.15 - 173.97$$

$$= 2401.18$$

$$u = h_f + h_{fg} - 100 P V_g$$

$$= 763 + 2013.5 - 1000 \times 10 \times 0.1933$$

$$= 2776.15 - 193.3$$

$$= 2583.2$$

Performance of the boiler ⟶

m_s → Mass of steam produced

m_f → ammount of fuel burnt

$$m_e = \frac{m_s}{m_f}$$

m_e ⟶ Equivalent mass

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wet, $h = h_f + x \cdot h_{fg}$
Dry, $h = h_f + h_{fg}$
superheated, $h = h_f + h_{fg} + C(T_{sup} - T_{sat})$

t_1 = feed water temperature
h_{f1} = Enthalpy of feed water

$$h_{f1} = 4.2 \times t_1$$

Total enthalpy = $h - h_{f1}$

Total heat required to produced stean = $m_e(h - h_{f1})$

Equivalent Evaporation →

$$E = \frac{\text{Total heat required to produce steam}}{\text{latent heat at } 100^\circ C}$$

$$E = \frac{m_e(h - h_{f1})}{2257}$$

Efficiency of boiler →

$$\eta = \frac{\text{Total heat required to produce steam}}{m_f \times C_v}$$

$$\eta = \frac{m_s(h - h_{f1})}{m_f \times C.V}$$

$$\eta = \frac{m_e(h - h_{f1})}{C.V}$$

Que. → A boiler evaporate 3.6 Kg of water per k.g of coal into dry saturated steam at 10 Bar. The temperature of feed water is 32°C. find the equivalent evaporation as well as factor of evaporation ?

m_e = 3.6 Kg / Kg of coal

t_1 = 32°C

P = 10 Bar

h_{f1} = 763 KJ / Kg

h_{fg} = 2013.5 KJ / kg

$$E = \frac{m_e (h - h_f)}{2257}$$

$$E = \frac{3.6 (h_f + h_{fg} - h_{f1})}{2257} = \frac{3.6 (763 + 2013.5 - 134.4)}{2257}$$

E = 4.2 Kg / Kg of coal.

$$\text{factor of evaporation} = \frac{h - h_{f1}}{2257}$$

$$\text{f.o.E} = \frac{763 + 2013.5 - 134.4}{2257}$$

f.o.E = 1.17

Que. → The following Observation were made in a boiler trial.

Coal used 250 Kg of calarific value 29800 KJ/kg

water evaporated 2000 Kg steam pressure 11.5 bar dryness fraction of steam 0.95 and feed water temperature 34°c. calculate the equivalent evaporation and efficiency of boiler.

$m_f = 250\ kg$

$m_s = 2000\ kg$

$$m_e = \frac{2000}{250} = 8\ kg/kg \text{ of coal}$$

$P = 11.5\ bar$

$h_f = 790\ kJ/kg.$

$h_{fg} = 199\ kJ/kg.$

$t_1 = 34°C$

$h_{f1} = 34 \times 4.2 = 142.8$

$h = h_f + x h_{fg}$

$h = 790 + 0.95(1991) = 2681.45$

$$\epsilon = \frac{m_e(h - h_{f1})}{2257} = \frac{8(2681.45 - 142.8)}{2257}$$

$\epsilon = 8.99\ kg/kg$ of coal.

$$\eta = \frac{m_e(h - h_{f1})}{C.V} = \frac{8(2681.45 - 142.8)}{29800}$$

$\eta = 0.68$

$\eta = 68\%$

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Que. → A coal fired boiler plant 400 kg of coal per hour. The boiler evaporate 3200 kg of water at 44.5°c into superheated steam at a pressure of 12 Bar and 274.5°C. If the calarific value of fuel is 32760 KJ/kg of coal. Determine equivalent evaporation and thermal efficiency of boiler. Assume specific heat of superheated steam of 2.1 KJ/kg K.

$t_1 = 44.5$ C $h_{f_1} = 44.5 \times 4.2 = 186.3$ KJ

$T_{sup} = 274.5$ °C

Pressure = 12 Bar

$C_v = 32760$ KJ/kg of coal

$m_s = 3200$ k.g

$m_f = 400$ k.g

$h_f = 798.7$ KJ/kg

$h_{fg} = 1984.1$ KJ/kg.

$T_{sat} = 188$°C

$h = 798.7 + 1984.1 + 2.1(274.5 - 188)$

$h = 2964.45$ KJ/kg

$m_e = \frac{m_s}{m_f} = \frac{3200}{400} = 8$

$E = \frac{m_e(h - h_f)}{2257} = \frac{8(2964.45 - 186.3)}{2257}$

$E = 9.85$ KJ/k.g of coal.

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$$\eta = \frac{m_e (h - h_{f1})}{C_v} = \frac{8 (2964.45 - 186.3)}{32760} = 68\%$$

Que.→ The following observation were made on a boiler plant during 1 hour test. steam pressure 20 Bar, steam temperature of water 15 °C, fuel used 4400. calarific value 30000 KJ/Kg of fuel. calculate the equivalent evaporation and thermal efficiency of the boiler. Assume specific heat of super heated steam 2.1 K.J/K.g K.

$t_1 = 15°C$

$T_{sup} = 260°C$

$P = 20$ Bar

$C_v = 30000$ KJ/Kg of fuel

$m_s = 37500$ Kg.

$m_f = 4400$ K.g $T_{sat} = 212.4°C$

$h_f = 908.6$ KJ/Kg $h_{fg} = 1888.4$ KJ/Kg

$$h = h_f + h_{fg} + C_p (T_{sup} - T_{sat})$$

$$h = 908.6 + 1888.4 + 2.1 (260 - 212.4)$$

$$h = 2797 + 2.1 (47.6)$$

$$h = 2797 + 99.96$$

$$h = 2896.96$$

$$m_e = \frac{m_s}{m_f} = \frac{37500}{4400} = 8.522$$

$$h_{f1} = 4.2 \times 15 = 63$$

$$\epsilon = \frac{m_e(h - h_{f1})}{C_V} = \frac{8.52(2896.93 - 63)}{2257}$$

$$\epsilon = 10.697$$

$$\eta = \frac{m_e(h - h_{f1})}{C_V} = \frac{8.52(2896.93 - 63)}{30000}$$

$$\eta = 0.80$$

$$\eta = 80\%$$

UNIT -5

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I.C ENGINE

I.C. Engine :- (Internal combustion engine)
I.C. Engine are those engines in which the combustion of fuel takes place inside engine cylinder.
These are :- (i) Petrol engine.
(ii) Diesel engine
(iii) Gas engine → LPG, CNG

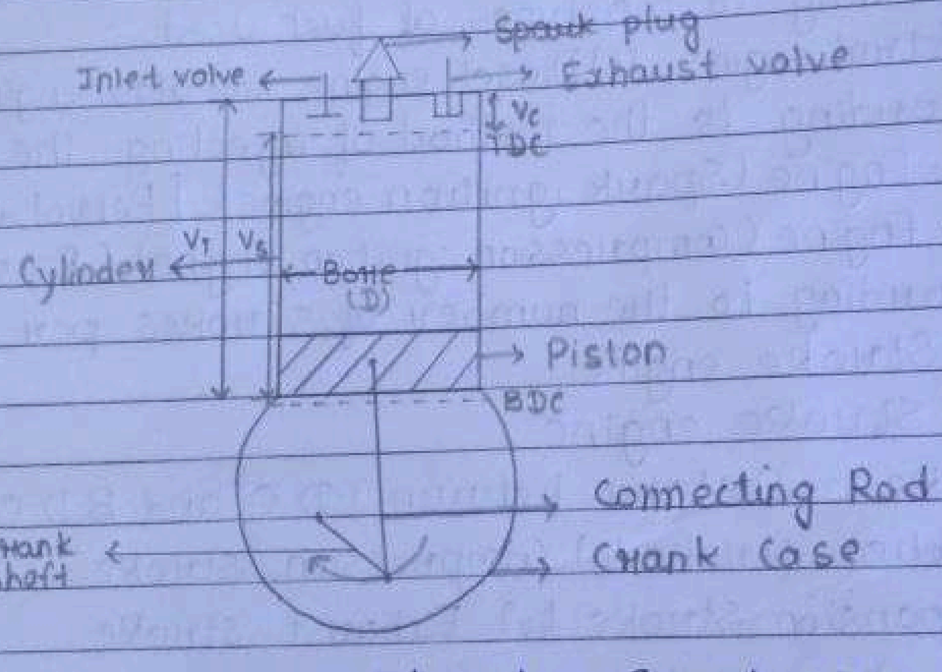
Classification of I.C. engine :-

(1) According to the types of fuel used :-
(i) Petrol engine, (ii) Diesel engine (iii) Gas engine
(2) According to the method of injecting the fuel :-
(i) S.I. Engine (Spark ignition engine) [Petrol engine]
(ii) C.I. Engine (Compression ignition engine) [Diesel engine]
(3) According to the number of strokes per cycle :-
(i) 2-Stroke engine
(ii) 4-Stroke engine
Stroke :- Distance between T.D.C and B.D.C.
(i) Suction stroke (ii) Compression stroke
(iii) Expansion stroke (iv) Exhaust stroke
(4) According to the cycle of operation :-
(i) Otto cycle (Volume constant)
(ii) Diesel cycle (Pressure constant)
(5) According to the speed of engine :-
(i) Slow speed engine (60-300 rpm) Revolution per minute
(ii) Medium speed engine (300-1200 rpm)
(iii) High speed engine (Above 1200 rpm)

(6) According to the cooling system :-
(i) Air ~ (fin) ~ two wheeler
(ii) Water (Radiator) ~ Four wheeler.

(7) According to the number of cylinder :-
(i) Single cylinder ~ (Two wheeler)
(ii) Multi cylinder ~ (Four wheeler)

Main component of I.C. engine :-



(i) Cylinder Head :- Inlet valve, Spark plug, Exhaust valve.

(ii) Piston :-
It is considered as heart of an I.C. engine, whose main function is to transmit force exerted by the burning of charge (fuel) to the connecting rod.
Made of aluminium alloy.

⇒ Bore (D) = Inner diameter of cylinder.

(iii) Piston rings :- made of special steel alloy.
upper (for leak proof of air).
lower (for leak proof of oil).

(iv) Connecting rod :-
It is link between the piston and crank shaft.
whose main function is to transmit force from the piston to the crank shaft.
It is made of special steel alloy or aluminium alloy.

(v) Crank shaft :-
It is considered as the backbone of an I.C. engine.
whose main function is to convert the reciprocating motion of the piston into the rotatary motion ~~of the~~ with the help of connecting rod.
It is made of special steel alloy.

(vi) Crank case
(vii) Cylinder

(viii) Flywheel :-
It is a big wheel, mounted (attach) on the crank shaft.
whose main function is to maintain its speed constant due to turning moment.
It is done by storing excess energy during the power stroke, which is return during other stroke.

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Difference between petrol and diesel engine

	Petrol Engine (S.I. Engine)	Diesel Engine (C.I. Engine)
1.	A petrol engine draws a mixture of petrol and air during suction stroke	A diesel engine draws only pure air during suction stroke
2.	The "carburettor" is employed to mix air and petrol in the required proportion and to supply it to engine cylinder during suction stroke.	The nozzle (fuel pump, fuel injector) is employed to inject the fuel at the end of compression stroke.
3.	Pressure at the end of compression is about 1 bar	Pressure at the end of compression is about 35 bar
4	The charge is ignited with the help of spark plug.	The charge is ignited with the help of nozzle.
5.	The combustion of fuel take place approximately at cons. volume. It works on auto cycle.	The combustion of fuel take place approximately at constant pressure. It works on diesel cycle.
6.	A petrol engine has compression ratio 6-10	A diesel engine has compression ratio 15 to 25.
7.	The starting is easy due to low compression ratio. $r = V_T/V_C = \frac{\text{Total Cylinder vol}^m}{\text{Clearance vol}^m}$	The starting is little difficult due to high compression ratio.
8.	The petrol engine are lighter and cheaper	The diesel engine are heavier and costly / costlier.
9	The running cost of a petrol engine is high	The running cost of diesel engine is low.
10.	The maintenance cost is less.	The maintenance cost is more

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	Petrol engine	Diesel engine
(11)	The thermal efficiency is upto about 26%. Q_s = heat supply, Q_R = heat injected. $\eta_{Th} = \frac{\text{Work done}}{\text{Heat Supply}} = \frac{Q_S - Q_R}{Q_S}$	The thermal efficiency is upto about 40%.
12.	These are high speed engine	These are relatively low speed engine.
13.	The petrol engines are generally employed in lite duty vehicles, cars. Such as:- Scooters, motorcycles, cars. These are used in aeroplane.	The diesel engine are generally employed in heavy duty vehicles. Such as:- Buses, trucks, train, earth moving machine, etc

* Advantages and Disadvantages of 2-stroke engine over 4-stroke engine:-

Advantages:-

1. In 2-stroke cycle engine gives twice the number of power strokes than the 4-stroke cycle engine at the same engine speed because of lower compression ratio.
2. For the same power developed, a 2-stroke cycle engine is lighter, less bulky and occupies less floor area. Thus it makes a 2-stroke cycle engine suitable for
3. A turning moment diagram of a 2-stroke cycle engine is more uniform, thus it makes a 2-stroke cycle engine to have a lighter flywheel and foundation.

4. The mechanical efficiency of a 2-stroke cycle engine is higher

$$\eta_{mec.} = \frac{\text{Brake power}}{\text{Indicated power}} \qquad I.P > B.P$$

5. The initial cost of a 2-stroke cycle engine is less than a 4-stroke cycle engine
6. The mechanism of a 2-stroke cycle engine is much simpler than a 4-stroke cycle engine
7. The two stroke cycle engines are much easier to start.

Disadvantages :-

1. The thermal efficiency of a 2-stroke cycle engine is less than that a 4-stroke cycle engine.
2. Overall efficiency of a 2-stroke cycle engine is also less than of a 4-stroke cycle engine.
3. The consumption of lubricating oil is large in a 2-stroke cycle engine because of high operating temperature.
4. Higher specific fuel consumption in 2-stroke than in 4-stroke.
5. The exhaust gases in a 2-stroke cycle engine creates noise because of short time available for their exhaust.

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6. Higher wear and tear in 2-stroke cycle engine.

* Clearance Volume (V_c) :-

The volume occupied by the working fluid. when piston reaches the top dead centre (TDC) is known as clearance volume.

* Stroke or Swept Volume (V_s) :-

The volume swept by the piston when it moves between T.D.C (Top dead centre) to B.D.C (Bottom dead centre) is known as swept volume or stroke volume. It is denoted by V_s.

* Total Volume of the cylinder (V) :-

The volume occupied by the working fluid, when the piston is at the bottom dead centre (B.D.C.) is known as total volume of the cylinder.

→ $V = V_c + V_s$

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4-Stroke cycle petrol engine :-

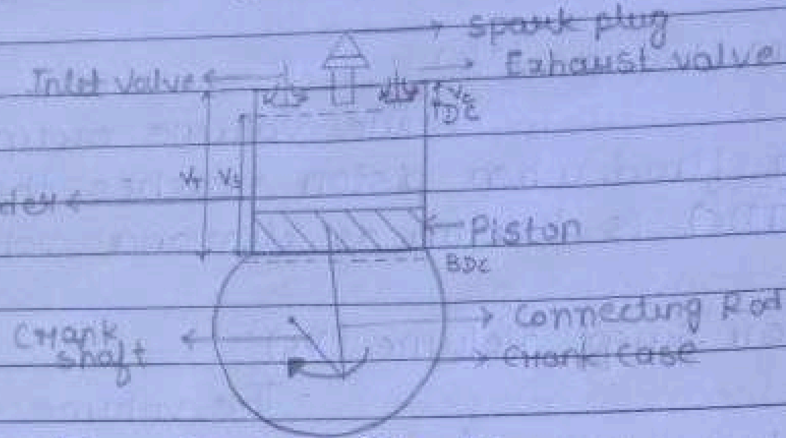

Fig:- Suction Stroke.

It is also known as auto cycle engine.
It requires four strokes of piston to complete one cycle of operation in the engine cylinder.

(1). Suction stroke:-
In this stroke the inlet valve opens and charge is sucked into the engine cylinder as the piston moves downwards from T.D.C. to B.D.C.

(2). Compression stroke:-

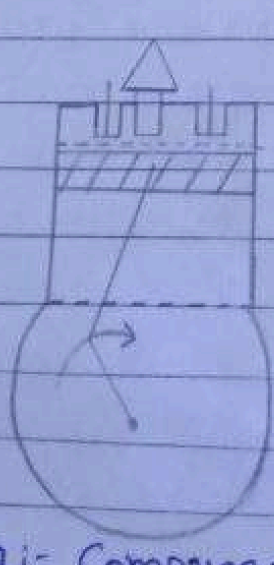

Fig:- Compression stroke

In this stroke both valve (inlet and exhaust) are closed and the charge is compressed as the piston moves ~~bet~~ towards (upwards) from B.D.C. to T.D.C. as a result of compression the pressure and temperature of the charge increases. This completes one revolution of the crank shaft.

(3) Expansion stroke :-

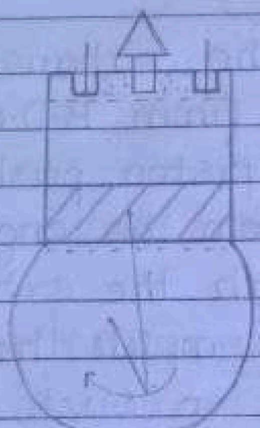

Fig:- Expansion stroke

In this stroke both valve are closed and piston moves from T.D.C. to B.D.C. Shortly before the piston reaches T.D.C. (During compression stroke) the charge is ignited with the help of spark plug. It suddenly increases the pressure and temperature of the products of combustion but the volume remains constant. Due to the ~~risin~~ rise in pressure the piston is pushed down with a great force. The hot burned gases expand due to high speed of piston. During this expansion some of the heat energy produced is transform into mechanical work.

(4) Exhaust stroke :-

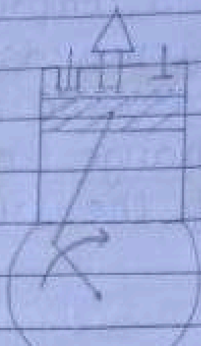

Fig:- Exhaust stroke

In this stroke the exhaust valve is open and piston moves from B.D.C. to T.D.C. This movement of the piston pushes out the products of combustion, from the engine cylinder and are exhausted through the exhaust valve into the atmosphere. This complete the cycle and engine cylinder is ready to suck the charge again.

Application / uses :-

The 4-stroke cycle petrol engine are usually employed in lightduty vehicles such as motor-cycles, scooters, cars, jeep and aeroplanes. etc

4-Stroke cycle diesel engine :-

It is also known as compression ignition engine because the ignition takes place due to the heat produced in the engine cylinder at the end of compression stroke.
The 4-strokes of diesel engine are described below :-

(1). Suction Stroke :-

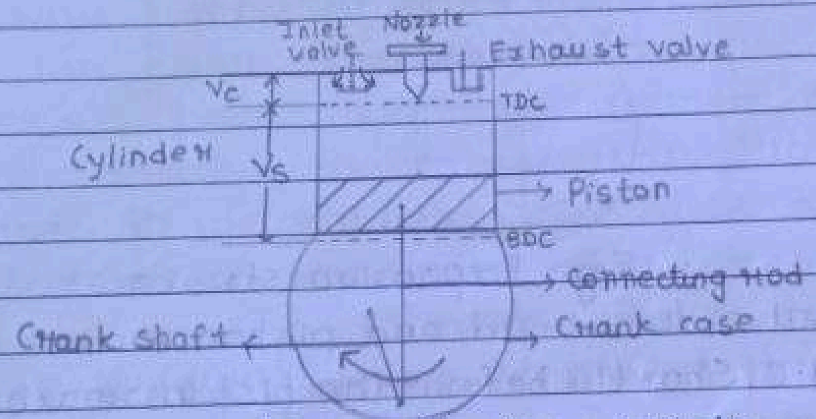

Fig → Suction Stroke

In suction stroke the inlet valve is open and pure air is sucked into the engine cylinder as the piston moves downwards from T.D.C. to B.D.C.

(2). Compression stroke :-

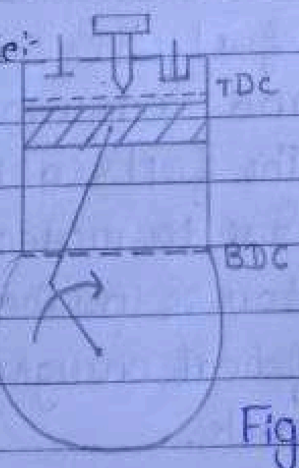

Fig → Compression Stroke

P.T.O.

(Inlet & Exhaust)
→ In Compression stroke both valve are closed and the charge is compressed as the piston moves upwards from Bottom dead center to top dead center. As a result of compression the pressure and temperature of the charge increases. This completes one revolution of the crank shaft.

(3) Expansion stroke:-

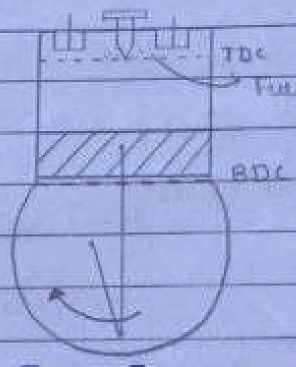

Fig:- Expansion stroke

Both valve are closed and piston moves from T.D.C to B.D.C. Shortly before the piston reaches the T.D.C, fuel injected in the form of very fine spray into the engine cylinder through the nozzle known as fuel injection valve.
At this movement of piston temperature of the compressed air is sufficiently high to ignite the fuel. It suddenly increase the pressure and temperature of products of combustion. The fuel is assumed to be burned at constant pressure. Due to increases pressure and temperature, piston is pushed down with a great force. The some of heat energy is transform into mechanical work.

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(4) Exhaust stroke :-

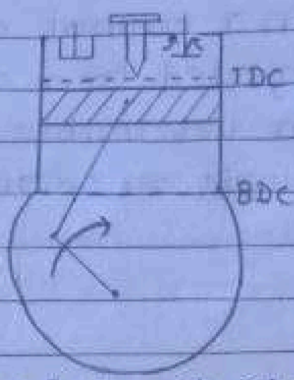

Fig → Exhaust stroke

In this stroke exhaust valve is open as piston moves from B.D.C. to T.D.C. This movement of the piston pushes out the products of comb- -ustion, from the engine cylinder and are exhaus -ted through the exhaust valve into the atmosp- -here. This completes the cycle and engine cylinder is ready to suck the charge again.

Application / Uses :-

The 4-stroke cycle diesel engine are used in heavy duty vehicles such as buses, trucks, trains, tractor, pumping set and earth moving machine, etc.

Carnot cycle :-

This cycle was devised by Dr. Sadi Carnot in 1824. In a carnot cycle the working substance is subjected to a cyclic operation consisting of two reversible isothermal and reversible isentropic or adiabatic operations.

$Q_S \Rightarrow 1\text{-}2$

$Q_R \Rightarrow 3\text{-}4$

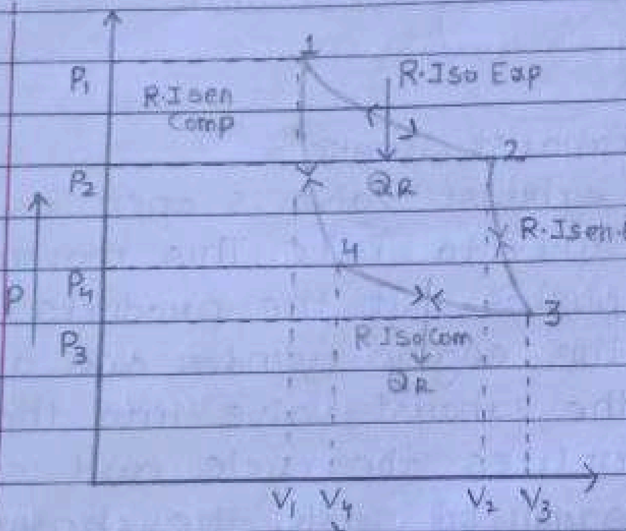

Fig :- P-V Diagram

2-R Isothermal (Temp constant)

2-R Isentropic (Entropy constant)

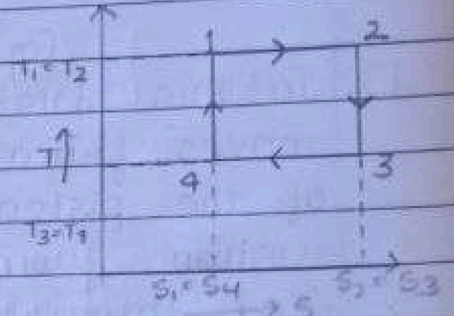

Fig :- T-S Diagram

(1) Firste stage 1-2 (Reversible Isothermal Expansion) process :-

In the first process 1-2, the heat is supplied at constant temperature to the cylinder head. The gas expands reversibally and isothermally.

$$Q_S = 2.3\, mRT_1 \log_e\left(\frac{V_2}{V_1}\right)$$

where $r = V_2/V_1$ = Expansion ratio of air

m = mass of Air in kg

R = Gas Constant = 287 J/kg-K for Air

T_1 = Temp. at point 1.

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(2) Second stage 2-3 (Reversible Isentropic Expansion) Process :-

In second stage process 2-3, the cylinder head is insulated and gas is allowed to expand reversibally and isentropically. The temperature of air falls T_2 to T_3. Since no heat is absorbed or rejected by the air.

(3) Third stage 3-4 (Reversible Isothermal Compression) Process :-

The third stage process 3-4, the air is compressed practically at a constant temperature from T_3 to T_4. It means that the temperature T_4 is equal to the Temperature T_3. The heat is rejected by the system/air.

$$Q_R = 2.3 mRT_3 \log_e\left(\frac{V_3}{V_4}\right)$$

$r = V_3/V_4 =$ compression ratio

$T_3 =$ Temp. at point 3

(4). Fourth stage 4-1 (Reversible Isentropic Compression) process :-

In the fourth stage process 4-1, the gas/air is compressed reversibally and isentropically. The temperature of the air is increases from T_4 to T_1. Since no heat is absorbed or rejected by the air.

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* Thermal or Air Standard or Ideal efficiency :-

$$\eta = \frac{\text{Work done}}{\text{Heat Supply}} = \frac{W}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$(\text{Air}) \;,, = \frac{2.3mRT_1\log_e\left(\frac{V_2}{V_1}\right) - 2.3mRT_3\log_e\left(\frac{V_3}{V_4}\right)}{2.3mRT_1\log_e\left(\frac{V_2}{V_1}\right)}$$

$$,, = \frac{2.3mR\log_e\frac{V_2}{V_1}(T_1 - T_3)}{2.3mR\log_e\frac{V_2}{V_1} \times T_1} \quad \left[\because \frac{V_2}{V_1} = \frac{V_3}{V_4}\right]$$

$$\boxed{\eta_{Air} = \frac{T_1 - T_3}{T_1} = 1 - \frac{T_3}{T_1}}$$

Ques. A carnot engine, working between 650K and 310K, produces 150KJ of work done. Find thermal efficiency and heat added during the process.

Solve.

$T_1 = 650\,K$, $T_2 = 310\,K$.

Work done = 150 KJ = 150×10^3 J

$$\eta = \frac{\text{Work done}}{\text{Heat supply}} = \frac{T_1 - T_3}{T_1}$$

$$\frac{150 \times 10^3}{Q_S} = \frac{650 - 310}{650}$$

$$\frac{150 \times 10^3}{Q_S} = 0.523$$

$$Q_S = 286.80 \times 10^3 J$$

$$Q_S = 286.80\,KJ$$

$$\eta = 52.3\%$$

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Otto cycle :-

This cycle was devised by Dr. Nicholas A. Otto in 1876. In Otto cycle, many gas and petrol engines run on this cycle. It is also known as "constant volume cycle", as the heat is received and rejected at a constant volume. The air is assumed to be the working substance.

The ideal otto cycle consists of two constant volume and two reversible isentropic (Adiabatic) processes.

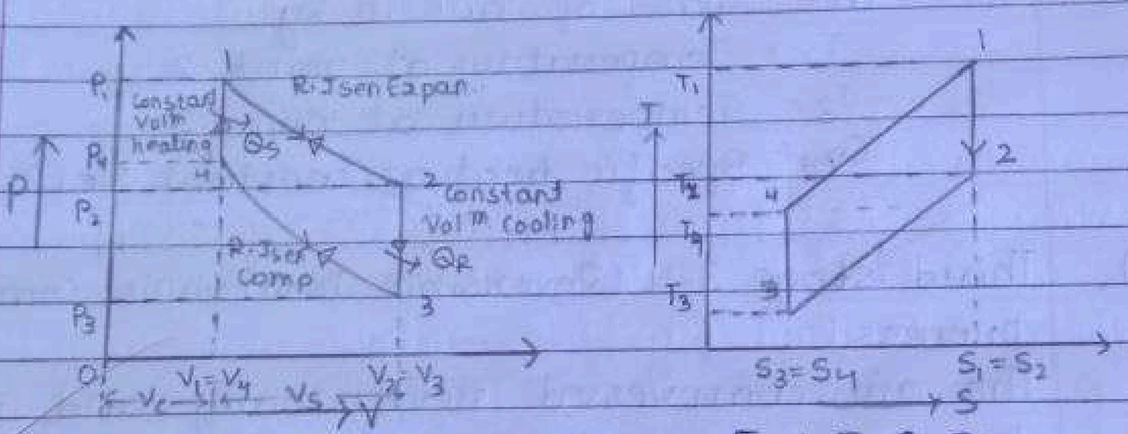

Fig :- P-V Diagram

Fig :- T-S Diagram

(1). First stage 1-2 (Reversible Isentropic Expansion) Process:-

In this process the air is expanded reversibally and isentropically from initial temperature T_1 to a temperature T_2. In this process, no heat is absorbed or rejected by the air.

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(2). Second stage 2-3 (Constant Volume cooling) process :-

In this process the air is cooled and at cons-tant volume from temperature T_2 to a temperature T_3. The heat is rejected by the air during this process.

$$(Q_R)_{2-3} = mC_V(T_2 - T_3)$$

m = mass of air in kg
T_2 = Temperature at point 2
T_3 = Temperature at point 3
C_V = Specific heat at constant Vol^m.

(3). Third stage 3-4 (Reversible Isentropic Compression) process :-

The air is compressed reversibally and isen-tropically from temperature T_3 to a tempe-rature T_4. In this process no heat is absorbed or rejected by the air.

(4) Fourth stage 4-1 (Constant Volume Heating) process :-

The air is heated at constant volume from temperature T_4 to a temperature T_1. The heat is absorbed or supply by the air during this process. $(Q_S)_{4-1} = mC_V(T_1 - T_4)$

* Thermal or Air standard or ideal efficiency :-

$$\eta_{TH} = \frac{W}{Q_S} = \frac{Q_S - Q_R}{Q_S} = \frac{mC_V(T_1 - T_4) - mC_V(T_2 - T_3)}{mC_V(T_1 - T_4)}$$

$$\eta_{TH} = 1 - \frac{(T_2 - T_3)}{(T_1 - T_4)}$$

$$\eta_{TH} = 1 - \frac{T_3\left(\frac{T_2}{T_3} - 1\right)}{T_4\left(\frac{T_1}{T_4} - 1\right)} \quad \text{—— (1)}$$

(1). We know that for reversible isentropic expansion process 1-2 :-

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

where γ = Isentropic index or constant and $\gamma = 1.4$ (For Air)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} \left[\because r = \frac{V_2}{V_1}\right] \text{—— (2)}$$

r = Expansion ratio

(2) For reversible isentropic compression process 3-4 :-

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} \left[\because r = \frac{V_3}{V_4}\right] \text{—— (3)}$$

r = Compression ratio

From equation (2) & (3), we find that

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = \left(\frac{1}{r}\right)^{\gamma-1}$$

$$\boxed{\frac{T_2}{T_3} = \frac{T_1}{T_4}}$$

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Substituting the value of T_1/T_4 in (1)

$$\eta_{TH} = 1 - \frac{T_3\left(\frac{T_2}{T_3} - 1\right)}{T_4\left(\frac{T_2}{T_3} - 1\right)}$$

$$\eta_{TH} = 1 - \frac{T_3}{T_4}$$

$$\boxed{\eta_{TH} = 1 - \left(\frac{1}{r}\right)^{\gamma - 1}}$$

η depends on r in otto cycle

We know,

In Isentropic process,

$$PV^{\gamma} = \text{Constant}$$

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} \quad \text{—(i)}$$

$$PV = mRT \quad (\text{Gas eq}^n)$$

$$\frac{PV}{T} = mR \quad (\text{Constant})$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2}$$

$$\frac{T_1}{T_2} = \frac{P_1}{P_2} \times \frac{V_1}{V_2}$$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}\left(\frac{V_1}{V_2}\right) \quad [\text{From (i)}]$$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}\left(\frac{V_2}{V_1}\right)^{-1}$$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma - 1}$$

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Questions:-

Ques. In otto cycle the temperature at the beginning and end of the isentropic compression are 316K and 596K respectively. Find out the Air standard efficiency and compression ratio. ($\gamma = 1.4$ (For Air))

Soln. We know, $\eta_{TH} = 1 - \frac{T_3}{T_4}$

where $T_3 = 316K$ and $T_4 = 596K$

Then, $\eta_{TH} = 1 - \frac{316}{596}$

$\eta_{TH} = 1 - 0.530$

$\eta_{TH} = 0.47$ or $\eta_{TH} = 47\%$

$\eta_{TH} = 1 - \frac{T_3}{T_4} = 1 - \left(\frac{1}{r}\right)^{\gamma-1}$

$0.47 = 1 - \left(\frac{1}{r}\right)^{1.4-1}$

$0.47 = 1 - \left(\frac{1}{r}\right)^{0.4}$

$\left(\frac{1}{r}\right) = 1 - 0.47 = 0.53$

$\left(\frac{1}{r}\right) = (0.53)^{1/0.4}$

$r = 4.9$

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Ques. In an Air standard otto cycle, the compression ratio is 7 and the compression begins at 1 bar and 331 K. The heat is added 2510 KJ per kg Find out (i) Maximum temperature an pressure of the cycle (ii) Work done per kg of Air. (iii) Cycle efficiency. [$\gamma = 1.4$]

Solⁿ (i) $\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1}$ [$V_4 = V_1, V_2 = V_3$]

$\frac{T_3}{T_4} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$

$T_3 = T_4 \times (7)^{\gamma-1} = 331 \times 7^{(1.4-1)} = 331 \times 7^{0.4}$

$T_3 = 331 \times 2.172$

$\boxed{T_3 = 720.587 K}$

(ii) $\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma} = \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma}$

$P_2 = P_1 (7)^{\gamma}$

$P_2 = 1 \cdot (7)^{1.4} = 1 \times 15.245$

$\boxed{P_2 = 15.245 \text{ Bar}}$

(iii) $\eta = 1 - \left(\frac{1}{7}\right)^{\gamma-1} = 1 - \frac{1}{7^{(1.4-1)}}$

$\eta = 1 - \frac{1}{2.17}$

$\eta = 1 - 0.46$

$\eta = 0.54$

$\boxed{\eta = 54\%}$

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Diesel Cycle :-

This cycle was deviced by Dr. Rudolph Diesel in 1893. In this cycle all diesel engines work. "This is also known as constant pressure cycle and it is received at a constant pressure."

The ideal diesel cycle consist of 2 - Reversible isentropic or 1 - constant volume and 1 - constant pressure

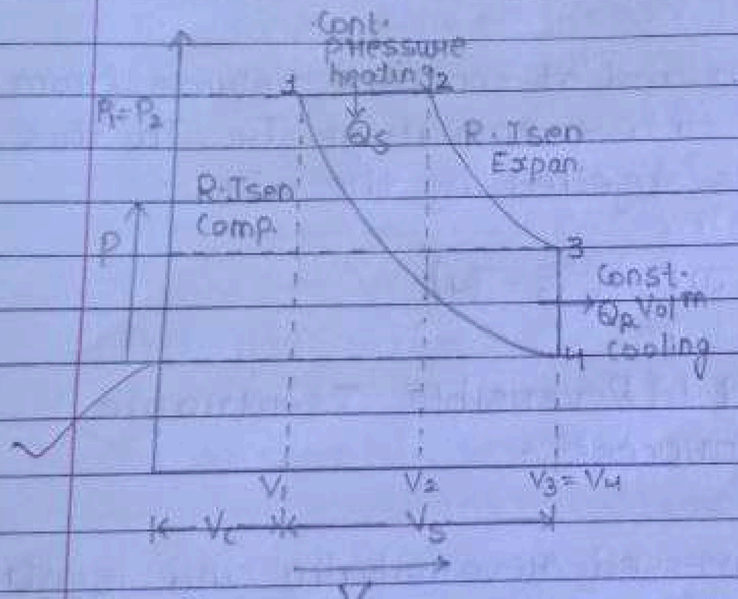

Fig :- Pressure and Volume diagram

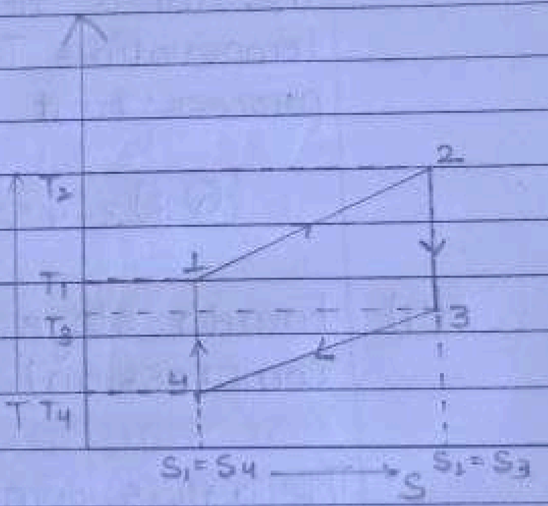

Fig :- T-S Diagram

1. First stage 1-2 (Constant pressure heating) process :-

The air is heated at constant pressure from intial temperature T_1 to a temperature T_2. In this process heat is supplied by the air

$$(Q_S)_{1-2} = mC_p(T_2 - T_1)$$

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(2) Second stage 2-3 (Reversible Isentropic Expansion) process:-

The air is expanded reversibally isentropically from temperature T_2 to a temperature T_3. In this process, no heat is absorb or rejected by the air.

(3) Third stage 3-4 (Constant volume cooling) process:-

The air is now cool at constant volume from temperature T_3 to a temperature T_4. In this process heat is rejected by the air.

$$(Q_R)_{3-4} = mC_v (T_3 - T_4)$$

(4) Fourth stage 4-1 (Reversible Isentropic Compression) process:-

The air is compressed reversibally and isentropically from temperature T_4 to a temperature T_1. In this process no heat is absorb or rejected by the air.

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* Air standard / Ideal / thermal / cycle efficiency :-

$$\eta_{TH} = \frac{W}{Q_S} = \frac{Q_S - Q_R}{Q_S}$$

$$\eta_{TH} = \frac{mC_p(T_2 - T_1) - mC_v(T_3 - T_4)}{mC_p(T_2 - T_1)}$$

$$\eta_{TH} = 1 - \frac{C_v(T_3 - T_4)}{C_p(T_2 - T_1)}$$

$$[\gamma = C_p / C_v = 1.4 \text{ (Air)}]$$

$$\eta_{TH} = 1 - \frac{1}{\gamma}\frac{(T_3 - T_4)}{(T_2 - T_1)} \quad \text{--- (i)}$$

Now let compression ratio

$$r = \frac{V_4}{V_1}$$

Cut off ratio, $\rho = \frac{V_2}{V_1}$

Expansion ratio, $r_1 = \frac{V_3}{V_2} = \frac{V_4}{V_1}$

$$r_1 = \frac{V_4}{V_2} \times \frac{V_1}{V_1}$$

$$r_1 = \frac{V_4}{V_1} \times \frac{V_1}{V_2}$$

$$r_1 = r \times \frac{1}{\rho}$$

$$\boxed{r_1 = \frac{r}{\rho}}$$

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We know For constant pressure heating process 1-2.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$T_2 = T_1 \times \frac{V_2}{V_1}$$

$$T_2 = T_1 \times \rho \quad \text{—— (ii)}$$

Similarly, for reversible isentropic expansion process 2-3

$$\frac{T_3}{T_2} = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$$

$$\frac{T_3}{T_2} = \left(\frac{1}{r_1}\right)^{\gamma-1}$$

$$\frac{T_3}{T_2} = \left(\frac{\rho}{r}\right)^{\gamma-1}$$

$$T_3 = T_2 \left(\frac{\rho}{r}\right)^{\gamma-1}$$

$$T_3 = T_1 \times \rho \left(\frac{\rho}{r}\right)^{\gamma-1} \quad \text{—— (iii)}$$

And for reversible isentropic compression process 4-1

$$\frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1}$$

$$\frac{T_1}{T_4} = (r)^{\gamma-1}$$

$$T_1 = T_4 \times (r)^{\gamma-1} \quad \text{—— (iv)}$$

Putting the value of T_1 in eq^n (ii) and (iii)

$$T_2 = T_4 \times (r)^{\gamma-1} \times \rho \quad \text{—— (v)}$$

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$$T_3 = T_4 \times (r)^{\gamma-1} \times \rho\left(\frac{\rho}{r}\right)^{\gamma-1}$$

$$T_3 = T_4 \times (r)^{\gamma-1} \times \rho \times \frac{\rho^{\gamma-1}}{r^{\gamma-1}}$$

$$T_3 = T_4 \times (r)^{\gamma-1} \times \rho \times \rho^{\gamma-1} \times r^{-\gamma+1}$$

$$T_3 = T_4 \times r^{\gamma-1-\gamma+1} \times \rho^{1+\gamma-1}$$

$$T_3 = T_4 \times \rho^{\gamma} \quad \text{—— (vi)}$$

Putting the value of T_1, T_2, T_3 in eq^n (i)

$$\eta_{air} = 1 - \frac{1}{\gamma} \frac{(T_4 \times \rho^{\gamma} - T_4)}{T_4 \times (r)^{\gamma-1}\rho - T_4 (r)^{\gamma-1}}$$

$$\eta_{air} = 1 - \frac{\rho^{\gamma} - 1}{\gamma (r)^{\gamma-1}(\rho - 1)}$$

$$\eta_{air} = 1 - \frac{(\rho^{\gamma} - 1)}{(r)^{\gamma-1}[\gamma(\rho-1)]}$$

NOTE:- 1. The efficiency of the ideal diesel cycle is lower than that of otto cycle for the same compression ratio this is due to fact that the cut off ratio (ρ) is always greater than unity.

2. The diesel cycle efficiency increases with decrease in cut off ratio (ρ)

$$\rho = \frac{V_2}{V_1}$$

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Question:-

1. In a diesel cycle, the compression ratio is 13 : 1 and fuel is cut off at 8 % of stroke. Find the air standard efficiency of the engine. Take $\gamma = 1.4$ for air.

Solution: Given.

$$\text{compression ratio } (r) = \frac{V_4}{V_1}$$

$$r = \frac{13}{1} = \frac{V_4}{V_1}$$

$V_4 = 13\,m^3$, $V_1 = 1\,m^3$

Cut off at 8 % of the stroke

$$\rho = \frac{V_2}{V_1}$$

$V_2 = V_1 + 8\%$ of V_s

V_s = Stroke volume

$V_2 = V_1 + 0.08 \times (V_4 - V_1)$

$V_2 = 1 + 0.08 \times (13 - 1)$

$V_2 = 1 + 0.08 \times 12$

$V_2 = 1 + 0.96$

$V_2 = 1.96\,m^3$

$$\rho = \frac{V_2}{V_1} = 1.96\,m^3$$

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Using formula,

$$\eta_{air} = 1 - \frac{(\rho^{\gamma} - 1)}{(r)^{\gamma-1}[\gamma(\rho - 1)]}$$

Here, $\gamma = 1.4$ (For Air), $\rho = 1.96\ m^3$, $r = 13$ ~~m^3~~

$$\eta_{air} = 1 - \frac{[(1.96)^{1.4} - 1]}{(13)^{1.4-1}[1.4(1.96-1)]}$$

$$\eta_{air} = 1 - \frac{2.56 - 1}{2.78(1.4 \times 0.96)}$$

$$\eta_{air} = 1 - \frac{1.56}{2.78(1.34)}$$

$$\eta_{air} = 1 - \frac{1.56}{3.72}$$

$$\eta_{air} = 1 - 0.42$$

$$\eta_{air} = 0.58$$

$$\eta_{air} = 58\%$$

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Assignment 1

Steam Engine:-

It is a device which converts heat energy into mechanical energy and heat is supplied with the engine through the medium of steam. It works on the principle of 1st law of thermodynamics.

In a steam engine high pressure superheated steam from boiler is fed into the steam chest. Here a D-shaped valve called D-slide valve, move to and fro in a steam chest and this valve regulates the supply of steam into the engine cylinder is operated by a mechanism E called eccentric which is situated on the crankshaft. There are two different parts A and B in which steam is led into the cylinder on the two sides of the piston and K is the exhaust port in which steam is led out ~~off~~ of the cylinder.

When D slide valve moves to the right, steam from steam chest enters from the left side through port A. This high-pressure steam pushes the piston to the right side of the crank end. This is called forward stroke of the piston.

With the movement of piston, crosshead moves to the right thus pushing the connecting rod which also pushes the crank to the right side.

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Now the crank and crankshaft both rotate in clockwise direction as shown in this picture.

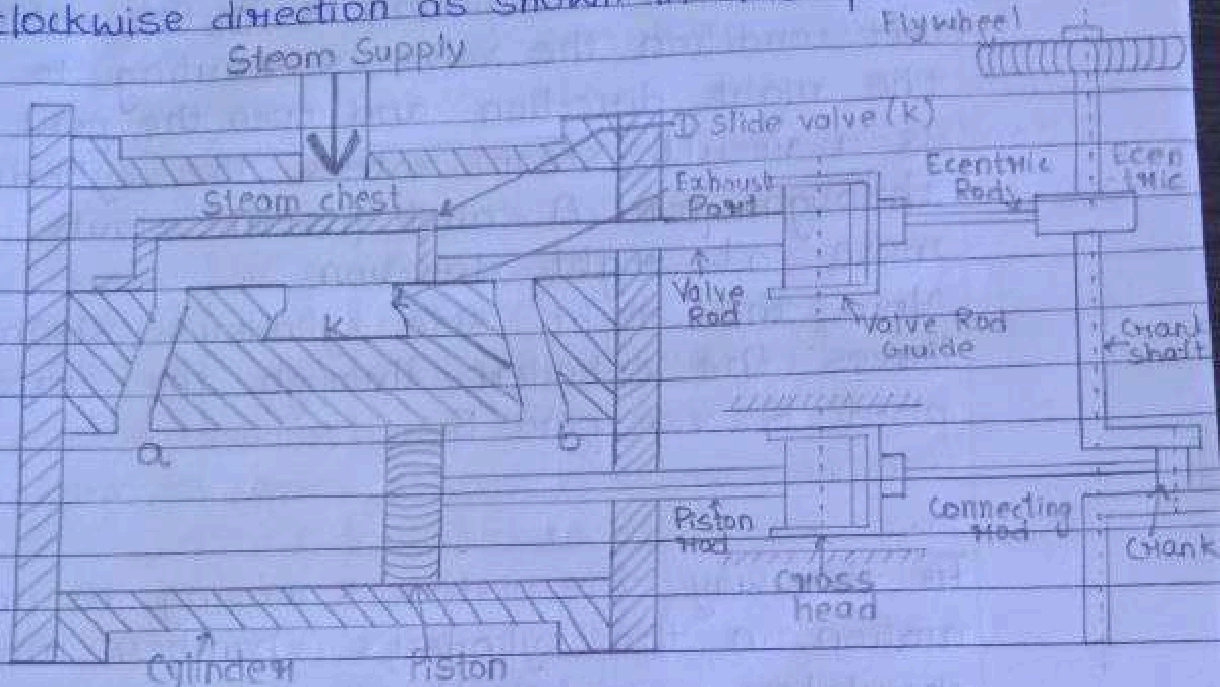

Fig 1- Components of steam engine

When piston is extremely right side or nearer to crank end cover, the valve is moving towards the left direction and open the steam port B in which steam is entering into the cylinder through this part. So, the piston is now moving left side direction or away from the crank. This is called the returned stroke of the piston. The piston is starting to move in left direction and left side steam leaves the cylinder through the exhaust port K via port A.

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Again when the piston is in the extreme left condition, the valve is starting to move the right direction and open the port A. As a result, steam enters the cylinder through port A and piston starts to move at right direction.
Now, the right side cylinder's steam leaves the cylinder through the exhaust port K via port B.

In this way, the piston is moving to and fro motion in the cylinder's chamber and it circulates crankshaft through piston rod, connecting rod and crank.
This process is continuously running and as such the steam engine works.
At the end of each stroke, the piston changes its direction of motion and it is momentarily stopped. This is called dead centres of the crank. The above steam engine is called single cylinder double acting horizontal reciprocating steam engine.

Hypothetical Indicator Diagram :-

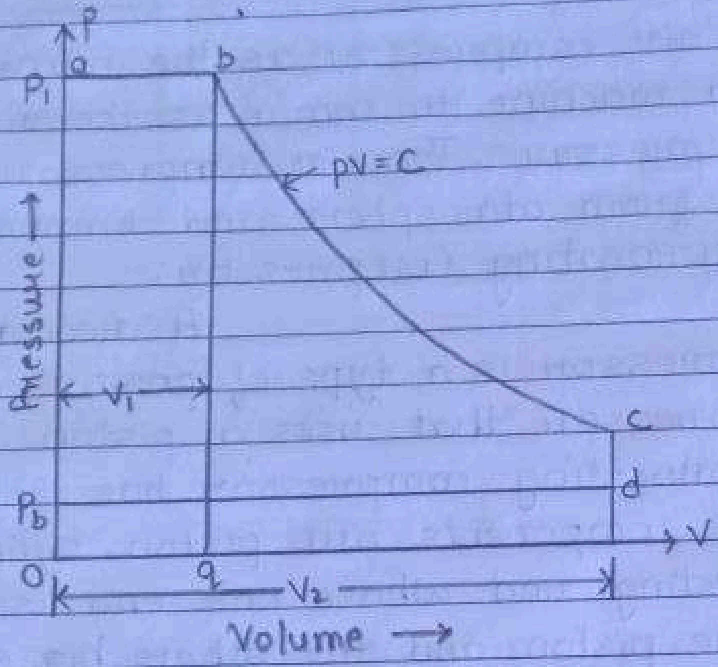

Fig:- Hypothetical Indicator Diagram

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Assignment-2

Ques. Explain the working principle of air compressor with the help of neat diagram.

Solution: An air compressor as the name indicates is a machine to compress the air and raises its pressure. The air compressor absorbs air from atmosphere and compress it.

Reciprocating Compressor:-

A reciprocating air compressor is a type of positive displacement compressor that uses a piston.

Reciprocating compressor has following main basic components are piston, cylinder and connecting rod whose one end is connected to the piston and the other big end connected to the crank. Fig 1. The inlet and outlet valve are also provided with the cylinder head which are operated by the pressure different across them. The piston reciprocates inside the cylinder which is either air cooled or water cooled.

When the piston moves in the downward direction the air trapped between the piston and the cylinder in the previous stroke (air in the clearance volume) expands and the pressure inside the cylinder decreases.

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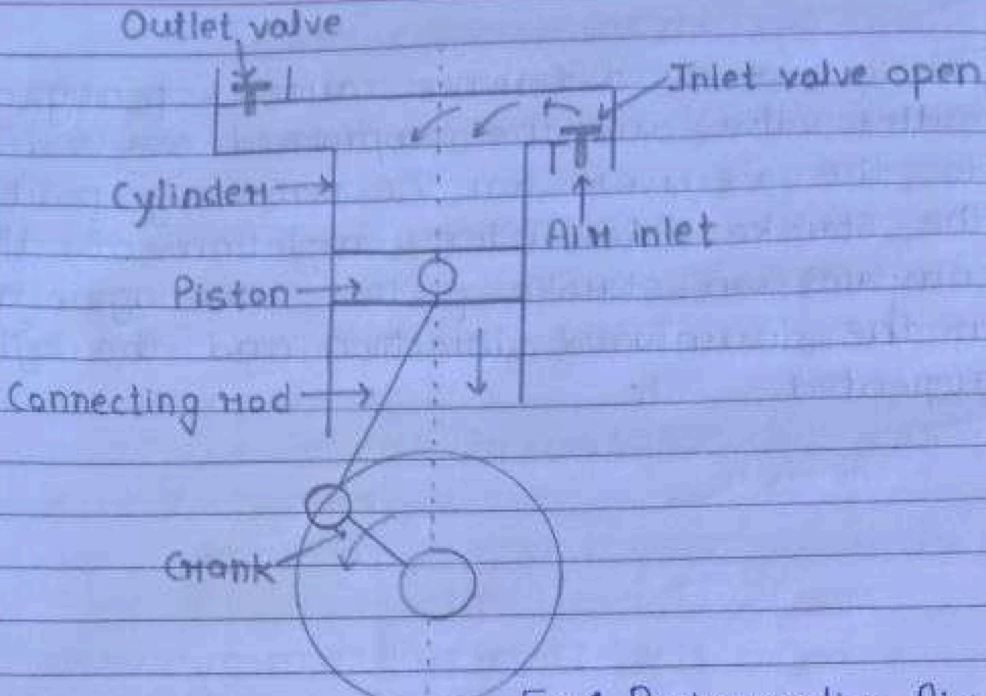

Fig.1 Reciprocating Air Compressor

As soon as the pressure inside the cylinder reaches a valve less than the intake manifold pressure the inlet valve opens. Thus a fresh charge of air is sucked inside the cylinder, for the remaining part of the suction stroke. During this process the outlet valve remains closed. When the piston moves in the upward direction the pressure inside the cylinder increases and as soon as the pressure inside the cylinder reaches a value more than the intake manifold pressure the inlet valve is closed. The further upward movement of piston increases the pressure of air traped inside the piston and the cylinder. Eventually, a pressure will be reached when the pressure inside the cylinder becomes more than the delivery pressure.

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This pressure difference causes opening of the outlet valve and the compressed air is delivered to the receiver for the remaining part of the stroke. ~~Afer~~ After completion of the compression stroke piston once again moves in the downward direction and the cyle is repeated.

A+

V. good