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2 Marks

Q.1

Sol. Because ECM works on electrochemical (electrolysis) principle and requires electrical conductivity of the workpiece.

KEY POINT:

Most Important One-Liners for Exam

- ECM works on Faraday's law of electrolysis
- EDM works on spark erosion
- USM uses abrasive slurry + ultrasonic vibration
- AJM uses high velocity abrasive jet
- LBM uses laser beam heat
- PAM uses plasma jet

Q.2

Sol. (a) **Taylor's Scientific Management**

F.W. Taylor is known as the Father of Scientific Management.

He introduced scientific methods to improve efficiency and productivity of workers.

Main Principles:

1. Science, not rule of thumb
2. Scientific selection and training of workers
3. Cooperation between management and workers
4. Equal division of work and responsibility

Contributions:

- Time study
- Standardization of tools and methods
- Differential piece rate system

Aim: Maximum output with minimum waste.

(b) Mayo's Human Relations Approach

Elton Mayo emphasized the importance of human factors in management.

His ideas are based on Hawthorne Experiments.

Main Points:

- Workers are motivated by social and psychological factors, not only money
- Good working environment improves productivity
- Teamwork and communication are very important

Conclusion: Happy workers = Higher productivity.

(c) Organization Chart

An organization chart is a diagrammatic representation of the structure of an organization showing authority and responsibility relationships.

Types:

1. Line organization chart
2. Functional organization chart
3. Line and staff organization chart

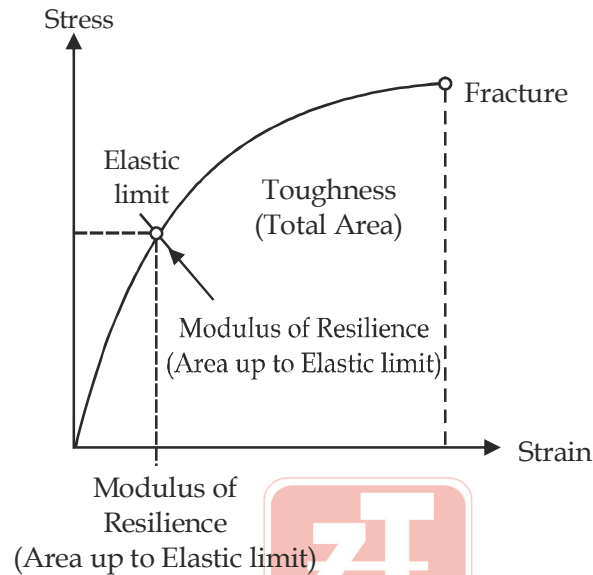
Importance:

- Shows clear authority relationships
- Avoids confusion and duplication of work
- Improves coordination and communication



Q.3

- Sol.
- The area under the stress-strain curve represents the strain energy absorbed per unit volume of the material.
 - Up to elastic limit, it is called modulus of resilience; for the whole curve, it represents toughness.



Q.4

- Sol.
- Therblig analysis breaks a job into basic human motions (like search, grasp, hold, transport, release, etc.).
 - It helps to identify unnecessary, ineffective and fatigue-causing motions and eliminate or simplify them, thereby improving productivity.

Q.5

Sol. Total observed time:

$$OT = 0.30 + 0.45 + 0.25 = 1.00 \text{ min}$$

Normal time:

$$NT = 1.00 \times 1.10 = 1.10 \text{ min}$$

Standard time:

$$ST = 1.10 \times 1.12 = 1.232 \text{ min}$$

$$ST = 1.232 \text{ min/cycle}$$

Q.6

Sol. T-T-T diagram is also called isothermal transformation diagram. It is a plot of temperature versus the logarithm of time for a steel alloy of definite composition. It is used to determine when transformation begin and end for an isothermal (constant temperature) heat treatment of a previously austenitized alloy.

Q.7

Sol.

Brazing

Filler metal melts above 450°C

Stronger joint

Soldering

Filler metal melts below 450°C

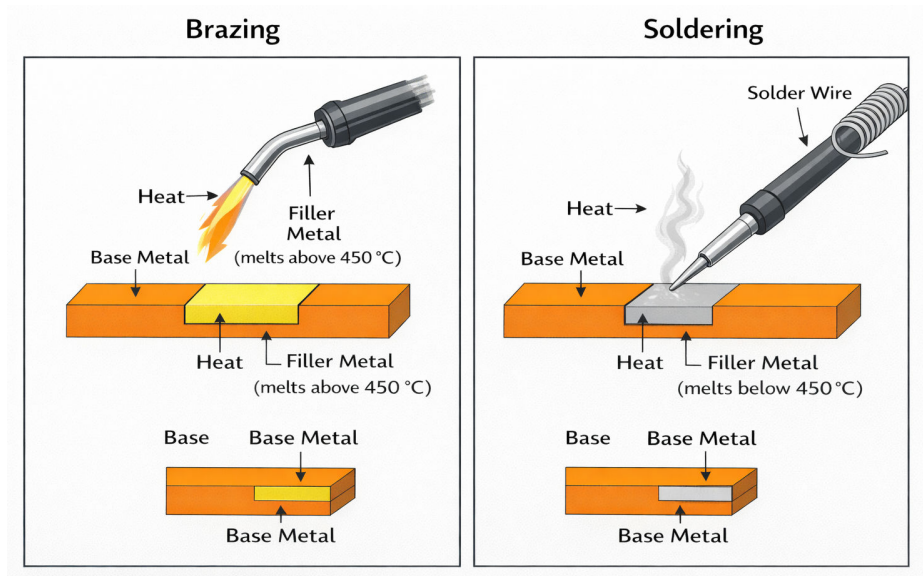
Comparatively weaker joint

Key Point:

- Brazing → Joining using high-melting filler (>450°C)



- Soldering → Joining using low-melting filler (<450°C)



Q.8

Sol. Some times it is not possible to provide sufficient support for a core in the mould being poured, if the cores are bigger in size. In such cases the core is supported with rigid metal pieces called chaplets.

Q.9

Sol. 1. The transformer maintenance cost is less.
2. Efficiency is very high.
3. The power available is very less.

Q.10

Sol. Given:

$$\Delta t = 2\text{mm}, R = 250 \text{ mm}$$

$$L \approx \sqrt{R\Delta t} = \sqrt{250 \times 2} = \sqrt{500} = 22.36 \text{ mm}$$

$$L \approx 22.36 \text{ mm}$$

Q.11

Sol. Difference between working stress and ultimate stress:

Working Stress	Ultimate Stress
It is the actual stress at which the machine part is designed to work safely.	It is the maximum stress a material can withstand before failure.
It is always less than the ultimate stress.	It is the highest stress obtained in a tensile test.
It includes factor of safety.	It is a material property.

Q.12

Sol. Macaulay's method is a modification of the double integration method used to find slope and deflection of beams carrying multiple point loads at different positions.

It uses a single equation for the entire length of the beam by introducing Macaulay brackets.

Q.13

Sol. The modified endurance limit is given by:

$$S_e = k_a k_b k_c k_d k_e k_f S_e'$$

Where:

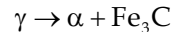
- S_e = Modified endurance limit
- S_e' = Theoretical (unmodified) endurance limit
- k_a = Surface finish factor
- k_b = Size factor
- k_c = Load factor
- k_d = Temperature factor
- k_e = Reliability factor
- k_f = Miscellaneous effects factor

Q.14

Sol. The eutectoid point in the iron-carbon equilibrium diagram is the point at which austenite (γ) transforms into ferrite (α) and cementite (Fe_3C) simultaneously at a fixed temperature and composition.

For Fe-C system:

- Carbon content = 0.8% (~0.77%)
- Temperature = 723°C
- Reaction:



(The product structure is called pearlite)

Q.15

Sol. As the percentage of carbon increases in steel:

- Hardness, strength and wear resistance increase
- Ductility, malleability and toughness decrease
- Weldability and machinability decrease

Q.16

Sol. • **Creep:** It is the slight relative motion caused by unequal stretching and contraction of the belt due to different tensions on the tight and slack sides.
• **Slip:** It is the actual sliding of the belt over the pulley due to insufficient frictional grip.

Q.17

Sol. A single-cylinder engine cannot be completely balanced because the unbalanced inertia forces of the reciprocating mass cannot be fully counteracted by rotating counterweights.

Q.18

Sol. **Coefficient of fluctuation of energy:** It may be defined as the ratio of the maximum fluctuation of energy to the work done per cycle. Mathematically, coefficient of fluctuation of energy,

$$C_E = \frac{\text{Maximum fluctuation of energy}}{\text{Work done per cycle}}$$

Q.19

Sol. Given:

$$T = 100 \text{ N.m}$$

$$\omega = 20 \text{ rad/s}$$

$$I = 1 \text{ kg-m}^2$$

$$T = I \times \omega \times \omega_p$$

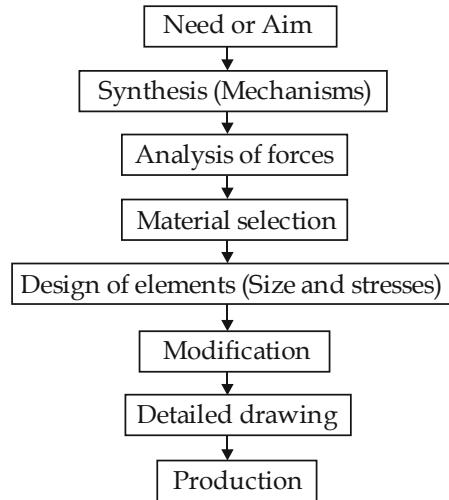
$$\Rightarrow 100 = 1 \times 20 \times \omega_p$$

$$\omega_p = 5 \text{ rad/s}$$



Q.20

Sol.



5 Marks

Q.21

Sol.

(1) Tool life at $V = 120$ m/min

$$VT^n = C \Rightarrow T^n = \frac{C}{V} = \frac{300}{120} = 2.5$$

$$T = (2.5)^{1/n} = (2.5)^{1/0.25} = (2.5)^4$$

$$T = 39.06 \text{ min}$$

(2) Speed for doubling tool life

$$T_2 = 2T_1 \Rightarrow V_1 T_1^n = V_2 T_2^n$$

$$V_2 = V_1 \left(\frac{T_1}{T_2} \right)^n = 120 \left(\frac{1}{2} \right)^{0.25}$$

$$2^{0.25} = \sqrt[4]{2} \approx 1.1892 \Rightarrow \left(\frac{1}{2} \right)^{0.25} = \frac{1}{1.1892} = 0.8409$$

$$V_2 = 120 \times 0.8409 = 100.90 \text{ m/min}$$

$$V_2 \approx 101 \text{ m/min}$$

$$T \approx 39.06 \text{ min}, V_2 \approx 101 \text{ m/min}$$

Q.22

Sol.

1. Meaning of Management Structure

Management structure refers to the framework of authority, responsibility and communication in an organization. It shows:

- Who will give orders
- Who will do the work

- Who is responsible to whom
In simple words, management structure defines the hierarchy and working system of an organization.
2. **Authority**
Authority is the right or power to give orders and take decisions and to expect obedience from subordinates.

Examples:

- Manager can assign work
- Supervisor can check work and guide workers

Features of Authority:

- It flows from top to bottom
- It is attached to the position, not the person
- It must be clearly defined

3. **Responsibility**

Responsibility is the duty or obligation to perform the assigned work properly.

Features of Responsibility:

- It flows from bottom to top
 - It cannot be delegated completely
 - A person who accepts authority must also accept responsibility
4. **Relationship between Authority and Responsibility**
Authority and responsibility must be equal and balanced.
- If authority > responsibility → Misuse of power
 - If responsibility > authority → Person cannot perform work properly

Correct Principle:

Authority = Responsibility

5. **Accountability (One line)**

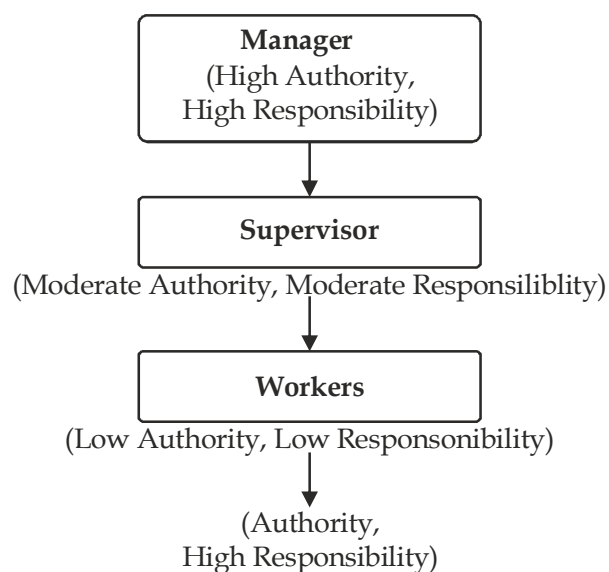
Accountability means being answerable for the result of work done.
Responsibility creates accountability.

One-line exam answers:

Authority → Right to command

Responsibility → Duty to perform

Accountability → Answerability for results



Q.23

Sol. (1) Modern Concept of Material Management

Material Management is the integrated function of planning, purchasing, storing, moving and controlling materials in such a way that:

- Right material is available
- In right quantity
- At right time
- At minimum total cost

Objectives:

- Reduce inventory cost
- Avoid shortage and overstocking
- Ensure smooth production flow
- Improve customer service and profitability

(2) Role of ABC Analysis (Selective Inventory Control)

ABC analysis classifies items based on annual consumption value:

- A items: High value, tight control ($\approx 70\%$ value, 10% items)
- B items: Moderate control
- C items: Simple control (many items, low value)

Contribution:

- Focuses management attention on critical items
- Reduces capital blocked in inventory
- Improves control efficiency at low cost

(3) Role of EOQ (Economic Order Quantity)

EOQ is the optimal order quantity that minimizes:

- Ordering cost
- Carrying (holding) cost

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Contribution:

- Decides how much to order
- Minimizes total inventory cost
- Avoids overstocking and frequent ordering

(4) Role of MRP-I (Material Requirement Planning)

MRP-I is a computer-based system that calculates:

- What material is needed?
- How much?
- When?

Based on:

- Master production schedule
- Bill of materials
- Inventory records

Contribution:

- Ensures timely availability of materials
- Reduces work-in-progress and shortages
- Improves production planning and scheduling

(5) Role of MRP-II (Manufacturing Resource Planning)

MRP-II is an extension of MRP-I which also includes:

- Machine capacity planning



- Manpower planning
- Financial planning

Contribution:

- Integrates material + capacity + finance
- Improves overall manufacturing control

(6) Role of ERP (Enterprise Resource Planning)

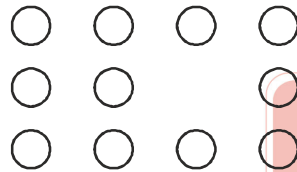
ERP is a fully integrated company-wide information system covering:

- Purchase
- Stores
- Production
- Finance
- HR
- Sales

Q.24

Sol. **Defects in metallic materials**

1. **Vacancy defect:-** It appears due to the missing of atom from the lattice.

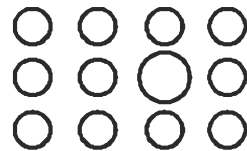


2. **Interstitial defect:-**

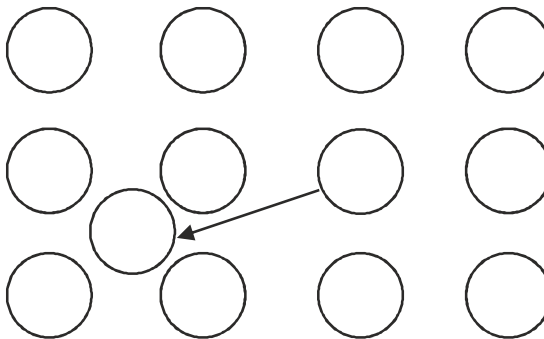


When the foreign atom occupies the interstitial site then the defect is called interstitial defect.

3. **Substitutional defect:-** If the regular atom is replaced by another foreign atom this defect is called substitutional defect.



4. **Frenkel defect:-** When the atom in the lattice point goes and occupies the interstitial void of other atom then it is called Frenkel defect.



5. **Schottky defect:-** If the combination of cation and anion from different places in lattice disappear and there is a vacancy defect then it is called Schottky defect.



Q.25

Sol. Chip thickness ratio

$$r = \frac{t_1}{t_2} = \frac{0.25}{0.50} = 0.5$$

Shear angle

$$\tan \phi = \frac{r \cos \alpha}{1 - r \sin \alpha}$$

$$\cos 10^\circ = 0.9848, \sin 10^\circ = 0.1736$$

$$\tan \phi = \frac{0.5 \times 0.9848}{1 - 0.5 \times 0.1736} = \frac{0.4924}{0.9132} = 0.5392$$

$$\phi = \tan^{-1}(0.5392) = 28.4^\circ$$

$$\boxed{r = 0.5, \phi \approx 28.4^\circ}$$

Q.26

Sol. (1) Cutting speed

$$V = \frac{\pi DN}{1000} = \frac{\pi(60)(500)}{1000} = 94.25 \text{ m/min}$$

Convert to m/s:

$$V = \frac{94.25}{60} = 1.571 \text{ m/s}$$

(2) MRR (turning)

$$\text{MRR} = \pi DN f d$$

$$= \pi(60)(500)(0.25)(2) = 47123.9 \text{ mm}^3/\text{min}$$

Convert to mm³/s:

$$\text{MRR} = \frac{47123.9}{60} = 785.4 \text{ mm}^3/\text{s}$$

$$\boxed{\text{MRR} \approx 785 \text{ mm}^3/\text{s}}$$

(3) Cutting force

Chip area:

$$A_c = f \times d = 0.25 \times 2 = 0.5 \text{ mm}^2$$

$$F_c = K_c A_c = 1800 \times 0.5 = 900 \text{ N}$$

(4) Cutting power

$$P = F_c \times V = 900 \times 1.571 = 1413.9 \text{ W}$$

$$\boxed{P \approx 1.41 \text{ kW}}$$

$$\boxed{\text{MRR} \approx 785 \text{ mm}^3/\text{s}, P \approx 1.41 \text{ kW}}$$

Q.27

Sol. Thin Pressure Vessel (Definition)

A pressure vessel is called thin when its wall thickness is very small compared to its diameter:

$$\frac{t}{d} \leq \frac{1}{20} \text{ (or } d \geq 20t)$$

So, stresses are assumed uniform across thickness.

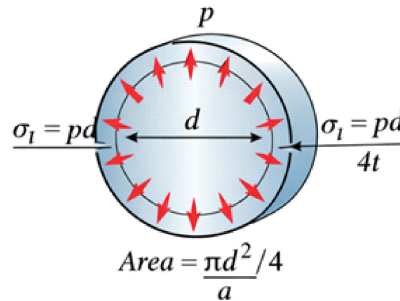
Thin Cylindrical Pressure Vessel Stresses

Let:

- Internal pressure = p
- Internal diameter = d
- Thickness = t
- Length = L

There are two main stresses:

1. Hoop (circumferential) stress σ_h
2. Longitudinal (axial) stress σ_l



Longitudinal Stress (Axial Stress) Derivation

Step: Consider cylinder cut by a transverse section

Pressure acts on circular area:

$$A = \frac{\pi d^2}{4}$$

$$\text{Force due to pressure} = \left(\frac{\pi d^2}{4} \right) p$$

Resisting area along circumference:

$$\text{Resisting area} = \pi d t$$

$$\text{Resisting force} = \sigma_l (\pi d t)$$

Equate forces:

$$p \left(\frac{\pi d^2}{4} \right) = \sigma_l (\pi d t)$$

Cancel πd :

$$p \left(\frac{d}{4} \right) = \sigma_l t$$

$$\sigma_l = \frac{p d}{4 t}$$

Final Result (Write in Box in Exam)

$$\sigma_h = \frac{p d}{2 t}$$

$$\sigma_l = \frac{p d}{4 t}$$

Also:

$$\sigma_h = 2 \sigma_l$$

Q.28

Sol. **Basic Definitions**

- **Load (w):** External force acting on a beam (kN/m or kN).
- **Shear Force (V):** Algebraic sum of all vertical forces acting on one side of a section.
- **Bending Moment (M):** Algebraic sum of moments of all forces about a section.

Fundamental Relationships

For a small beam element of length dx:

(1) Relationship between Load and Shear Force

$$\frac{dV}{dx} = -w$$

Meaning:

The rate of change of shear force with respect to x is equal to the negative of load intensity.

(2) Relationship between Shear Force and Bending Moment

$$\frac{dM}{dx} = V$$

Meaning:

The rate of change of bending moment with respect to x is equal to the shear force.

(3) Combined Relationship

$$\frac{d^2M}{dx^2} = -w$$

Nature of Diagrams

Load	SFD	BMD
No load	Constant	Straight line
Point load	Sudden jump	Straight line
UDL	Straight line	Parabola
UVL	Parabola	Cubic curve

Q.29

Sol. A crystal system is a classification of crystals based on the geometry of their unit cell, i.e., based on:

- Relative lengths of axes (a, b, c)
- Angles between axes (α, β, γ)

All crystalline materials are classified into seven crystal systems.

The Seven Crystal Systems

No.	Crystal System	Axial Lengths	Angles Between Axes	Examples
1	Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Fe, Cu, Al
2	Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	SnO_2 , White tin
3	Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	Sulphur
4	Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ, \gamma = 120^\circ$	Mg, Zn
5	Trigonal (Rhombohedral)	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	Quartz
6	Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ, \beta \neq 90^\circ$	Gypsum
7	Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	Feldspar

Q.30

Sol. **Types of Straight-Line Mechanisms:** Straight-line mechanisms are classified into two main types:

- 1. Exact Straight-Line Mechanisms:** These mechanisms generate a perfect straight-line motion.
Examples: Peaucellier-Lipkin mechanism, Hart's mechanism.
- 2. Approximate Straight-Line Mechanisms:** These mechanisms produce an approximately straight-line motion over a limited range.
Examples: Watt's mechanism, Tchebicheff mechanism, Scott-Russell mechanism.



Q.31

Sol. Pressure angle:

- The angle between the pressure line and common tangent to the pitch circle is called Pressure angle or angle of obliquity.

Involute profile:

- It is defined as the locus of the point on the line which rolls without slipping on the fixed circle.
- In involute gears, the pressure angle, from the start of the engagement of teeth to the end of the engagement, remains constant. It is necessary for smooth running and less wear of gears.
- But in cycloidal gears, the pressure angle is maximum at the beginning of engagement, reduces to zero at pitch point, starts increasing and again becomes maximum at the end of engagement. This results in less smooth running of gears.

Q.32

Sol. Leading and trailing shoes are the two friction-lined components in a drum brake system that press against the inner surface of a rotating drum to slow it down.**Key Differences and Characteristics:****Leading Shoe (Primary Shoe):****Direction:** Rotates in the same direction as the brake drum.**Action:** It "wedges" into the drum due to friction, enhancing braking pressure.**Performance:** Provides stronger braking force due to the self-servo (self-energizing) effect.**Wear:** Experiences higher wear rates.**Trailing Shoe (Secondary Shoe):****Direction:** Moves opposite to the direction of the drum's rotation.**Action:** The drum's rotation tends to push it away, reducing its effective pressure.**Performance:** Provides lower braking force.**Function:** Often acts as the primary braking shoe when the vehicle is in reverse.20 Marks

Q.33

Sol. Maintaining an inventory is necessary because of the following reasons:

- It helps in smooth and efficient running of an enterprise. It decouples the production from customers and vendors and simplifies the otherwise complex organisation for manufacture and reduces the co-ordination effort.
- It provides services to the customer at a short notice. Timely deliveries can fetch more goodwill and orders.
- In the absence of inventory, the enterprise may have to pay high prices because of piecemeal purchasing. Maintaining of inventory may earn price discount because of bulk purchasing. It also takes advantage of favourable market.
- It reduces product costs since there is an added advantage of batching and long, uninterrupted production runs.
- It acts as a buffer stock when raw materials are received late and shop rejections are too many.
- Process and movement inventories (also called pipeline stocks) are quite necessary in big enterprises where significant amount of time is required to transship items from one location to another.
- Bulk purchases will entail less orders and, therefore, less clerical costs. This applies to goods produced within the organisation as well. Less orders, as a result of larger lots, will entail lesser machine setups and other associated costs.
- An organisation may have to deal with several customers and vendors who are not necessarily near it. Inventories, therefore, have to be built to meet the demand at least during the transit time.
- It helps in maintaining economy by absorbing some of the fluctuations when the demand for an item fluctuates or is seasonal.



Each order has associated with it the ordering cost or acquisition cost. To keep it low, the number of orders should be as few as possible. i.e., the order size should be large. But large order size would imply high inventory carrying cost. Hence the need of optimisation of order quantity is arisen.

Given, Demand, $D = 10,000$ pieces/ year. Order cost, $C_0 = \text{Rs. } 240/\text{order}$

Inventory carrying cost or holding cost = 1% of Rs. 50/month

$$C_h = \frac{1}{100} \times 50 \times 12 / \text{year} = \text{Rs. } 6 / \text{year} / \text{item}$$

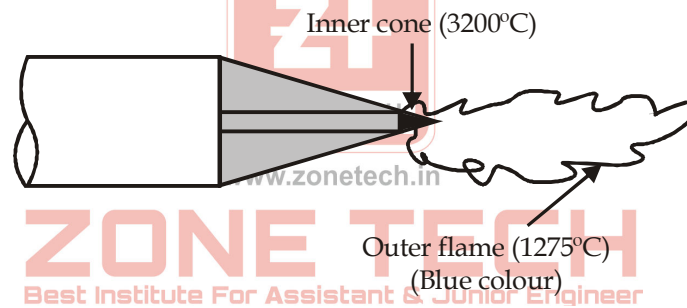
$$\text{EOQ} = \sqrt{\frac{2DC_0}{C_h}} = \sqrt{\frac{2 \times 240 \times 10000}{6}} = 894.42 \text{ components} / \text{procurement}$$

Q.34

Sol. To achieve successful and efficient welding proper mixing of gases in appropriate proportion is important. According to the volume of oxygen and acetylene, flames can be classified as:

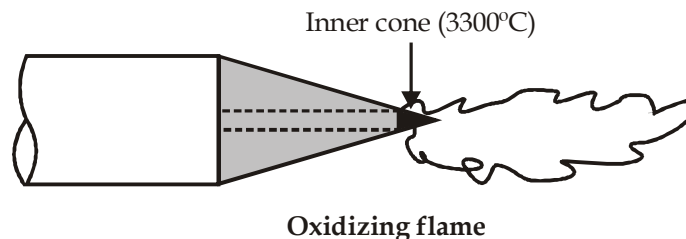
(i) **Neutral flame:**

It is produced when equal volume of oxygen and acetylene are mixed. Neutral flame does not create any chemical change in the molten metal and does not oxidize or carburize the metal. Flame is used for welding of cast iron, aluminium and stainless steel. It produces hissing sound.



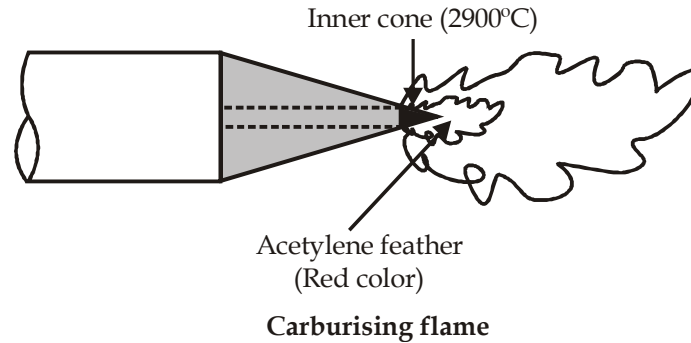
(ii) **Oxidizing flame:**

Oxidizing flame is obtained by increasing the supply of oxygen in mixture. It has small white cone that is shorter and more pointed than that of neutral flame. It is normally not used except in case of brass. It produces roaring sound.



(iii) **Carburizing flame:**

It is produced when supply of acetylene is higher than supply of oxygen and can create an approximate temperature of 3038°C. It can be identified by acetylene feather. It is used for welding of lead.



The advantages of Oxy Acetylene Welding are :

- It is simple in construction, no huge parts and equipment are used in its installation like Arc Welding.
- It is easy to operate and no need for highly skilled technicians to operate it.
- Not only for welding but also oxy acetylene is used to separate or cut the materials into pieces.
- This type of Welding is cheaper.
- As Oxy Acetylene uses the gases like oxygen and acetylene, it can be used to weld ferrous and even non-ferrous metals.
- The intensity of the flame can be adjusted to high and less by using the valve.
- It can be used for high melting metals and even for low melting metals.

The disadvantages of Oxy Acetylene Welding are :

- The temperature of the flame is less when compared to the arc welding.
- As like arc welding, the oxy acetylene does not have a high flux shield over the weld.
- It is suitable for thin materials and medium thin materials whereas it is not suitable for thick materials.

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Q.35

Sol.

1. **Case Hardening Steels:-** These usually contain less than 0.15% carbon. As carbon content is low, the core does not respond to hardening. By adding about 3% nickel and 0.45% manganese, these do not require further refining after carburising. Such a steel can be water-quenched and is used for gudgeon pins, camshafts, etc. If percentage of nickel is increased to 5% then oil-quenching can be used for hardening. Such a steel is used for gearbox parts, etc.
2. **Nitriding Steels:-** These contain carbon from 0.4 to 0.5%. Accordingly these respond to direct hardening and a high strength case is developed after hardening and tempering. It may contain chromium between 1.6 to 3%. It is used when a high-strength core and a high hardness case are required. With 3% chromium, surface hardness of about 850 HV can be developed and when 1.1% aluminium is also added, then surface hardness of the order of 1100 HV can be developed.
3. **High-Tensile Steels:-** These contain carbon of the order of 0.3 to 0.4%. Addition of 3% nickel and 0.6% fine grain structure. It can then be oil-quenched and is used for crank-shafts, connecting rods etc. A further addition of 0.8% chromium makes steel suitable for highly stressed parts. However it suffers from temper brittleness which can be prevented by specifying the tempering temperature. (It should not be tempered at particular temperature which depends upon composition). Another method to overcome temper brittleness is to add 0.25% molybdenum. With 4.25% nickel and 1.25% chromium, steel becomes suitable for air-hardening and can be used for complex shapes, but it also suffers from temper brittleness. A further addition of 0.45% vanadium and 1% silicon (1.25% molybdenum to remove temper brittleness) makes it suitable for forging dies, die-casting dies and extrusion press dies.
4. **Wear-Resisting Steels:-** These contain carbon from 1 to 1.2%. Addition of 12.5% manganese makes austenite to be retained as a result of heating and quenching. This is known as 'Hadfields' austenitic steel which responds to work hardening and becomes harder as a result of rough treatment. Accordingly it is used for track work, dredging equipment and crushing machinery. Steels with 1.4% chromium and 0.45% manganese can be oil-quenched and are very hard and used for roller and ball races.



5. **Heat Resisting Steels:-** These contain carbon varying between 0.15% and 0.3%. To make them corrosion resistant, 12 to 16% chromium is added. While chromium also improves the strength, other elements like carbon, tungsten, molybdenum strengthen the alloy. These also resist oxidation and attack by vapour and gases at high temperature. They also retain their strength at high temperatures and resist creep. Steel used for turbine blades and dies for use upto 600°C contains 0.15% C, 1% Mn, 12% Cr and 1% Ni. Some of the heat resisting steels respond to heat treatment and some can be hardened only by working.

Q.36

Sol. **Given:**

$$\begin{array}{llllll} m_1 = 200 \text{ kg;} & m_2 = 300 \text{ kg;} & m_3 = 240 \text{ kg;} & & m_4 = 260 \text{ kg;} \\ r = 0.2 \text{ m;} & r_1 = 0.2 \text{ m;} & r_2 = 0.15 \text{ m;} & r_3 = 0.25 \text{ m;} & r_4 = 0.3 \text{ m;} \\ \theta_1 = 0^\circ; & \theta_2 = 45^\circ; & \theta_3 = 45^\circ + 75^\circ = 120^\circ; & & \theta_4 = 45^\circ + 75^\circ + 135^\circ = 255^\circ \\ \text{Let} & m = \text{Balancing mass, and} & & & \\ & \theta = \text{The angle which the balancing mass makes with } m_1. & & & \end{array}$$

Since the magnitude of centrifugal forces are proportional to the product of each mass and its radius, therefore

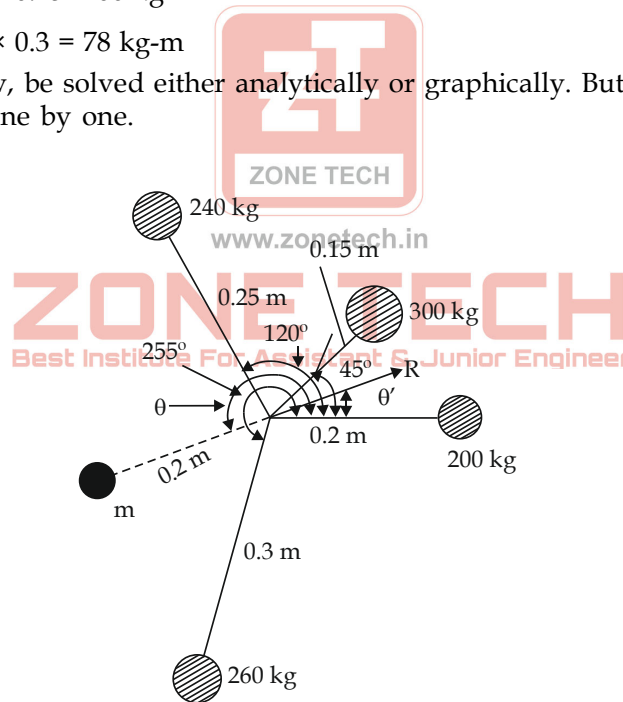
$$m_1 \cdot r_1 = 200 \times 0.2 = 40 \text{ kg-m}$$

$$m_2 \cdot r_2 = 300 \times 0.15 = 45 \text{ kg-m}$$

$$m_3 \cdot r_3 = 240 \times 0.25 = 60 \text{ kg-m}$$

$$m_4 \cdot r_4 = 260 \times 0.3 = 78 \text{ kg-m}$$

The problem may, now, be solved either analytically or graphically. But we shall solve the problem by both the methods one by one.



1. Analytical method

The space diagram is shown in Fig.

Resolving $m_1 \cdot r_1$, $m_2 \cdot r_2$, $m_3 \cdot r_3$ and $m_4 \cdot r_4$ horizontally,

$$\begin{aligned} \Sigma H &= m_1 \cdot r_1 \cos \theta_1 + m_2 \cdot r_2 \cos \theta_2 + m_3 \cdot r_3 \cos \theta_3 + m_4 \cdot r_4 \cos \theta_4 \\ &= 40 \cos 0^\circ + 45 \cos 45^\circ + 60 \cos 120^\circ + 78 \cos 255^\circ \\ &= 40 + 31.8 - 30 - 20.2 = 21.6 \text{ kg-m} \end{aligned}$$

Now resolving vertically,

$$\begin{aligned} \Sigma V &= m_1 \cdot r_1 \sin \theta_1 + m_2 \cdot r_2 \sin \theta_2 + m_3 \cdot r_3 \sin \theta_3 + m_4 \cdot r_4 \sin \theta_4 \\ &= 40 \sin 0^\circ + 45 \sin 45^\circ + 60 \sin 120^\circ + 78 \sin 255^\circ \\ &= 0 + 31.8 + 52 - 75.3 = 8.5 \text{ kg-m} \end{aligned}$$

$$\therefore \text{Resultant, } R = \sqrt{(\sum H)^2 + (\sum V)^2} = \sqrt{(21.6)^2 + (8.5)^2} = 23.2 \text{ kg-m}$$

We know that

$$m \cdot r = R = 23.2 \text{ or } m = 23.2/r = 23.2/0.2 = 116 \text{ kg}$$

$$\tan \theta' = \sum H / \sum V = 8.5 / 21.6 = 0.3935 \text{ or } \theta' = 21.48^\circ$$

Since θ' is the angle of the resultant R from the horizontal mass of 200 kg, therefore the angle of the balancing mass from the horizontal mass of 200 kg,

$$\theta = 180^\circ + 21.48^\circ = 201.48^\circ \text{ Ans.}$$

2. Graphical method

The magnitude and the position of the balancing mass may also be found graphically as discussed below :

1. First of all, draw the space diagram showing the positions of all the given masses as shown in Fig.
2. Since the centrifugal force of each mass is proportional to the product of the mass and radius, therefore

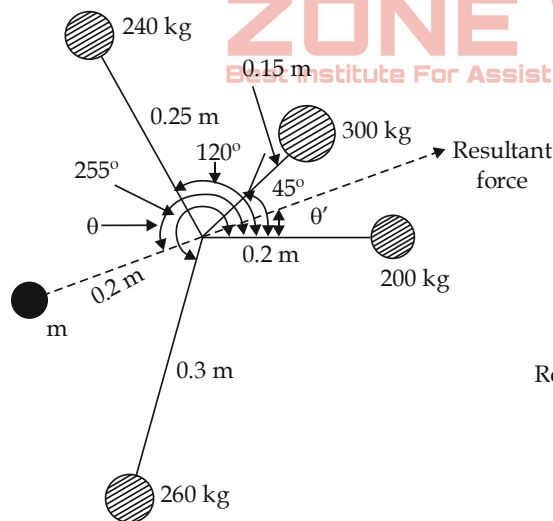
$$m_1 \cdot r_1 = 200 \times 0.2 = 40 \text{ kg-m}$$

$$m_2 \cdot r_2 = 300 \times 0.15 = 45 \text{ kg-m}$$

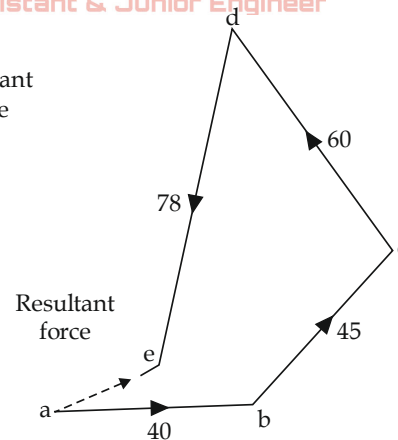
$$m_3 \cdot r_3 = 240 \times 0.25 = 60 \text{ kg-m}$$

$$m_4 \cdot r_4 = 260 \times 0.3 = 78 \text{ kg-m}$$

3. Now draw the vector diagram with the above values, to some suitable scale, as shown in Fig. (b). The closing side of the polygon ae represents the resultant force. By measurement, we find that $ae = 23 \text{ kg-m}$.



(a) Space diagram



(b) Vector diagram

4. The balancing force is equal to the resultant force, but opposite in direction as shown in Fig. (a). Since the balancing force is proportional to $m \cdot r$, therefore

$$m \times 0.2 = \text{vector } ea = 23 \text{ kg-m or } m = 23/0.2 = 115 \text{ kg Ans.}$$

By measurement we also find that the angle of inclination of the balancing mass (m) from the horizontal mass of 200 kg,

$$\theta = 201^\circ \text{ Ans.}$$

Q.37

Sol. Given that

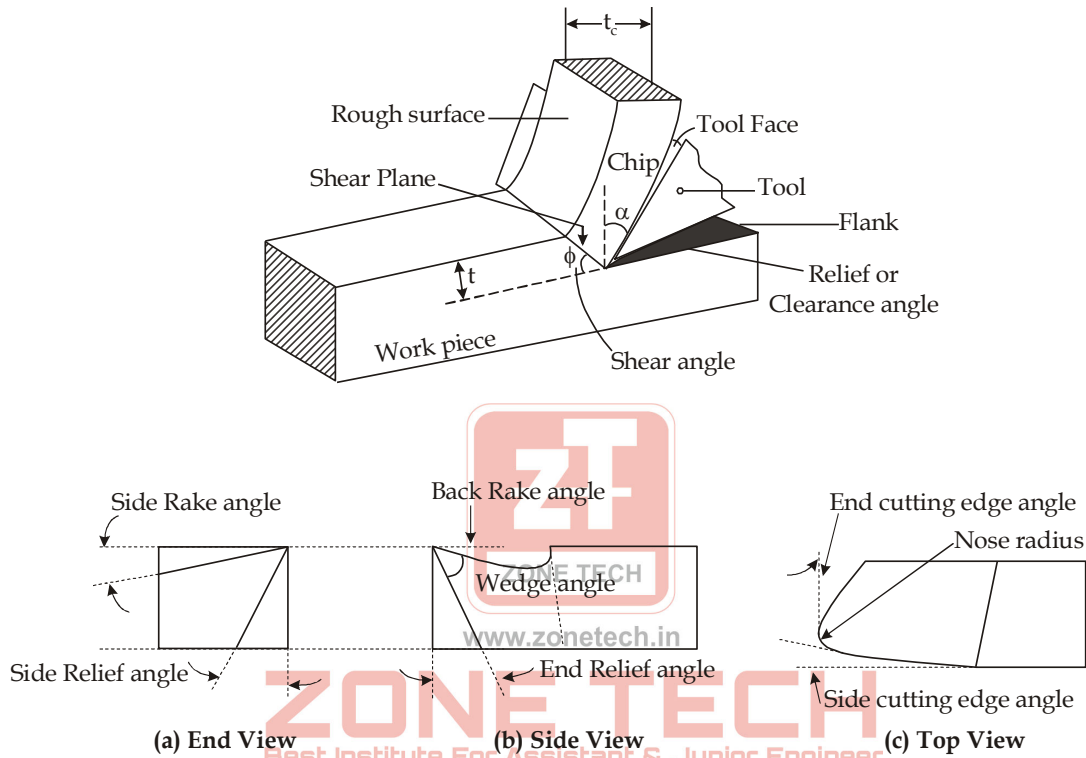
α = Rake angle

ϕ = Shear angle

Ψ = Lip angle/Wedge angle/Cutting angle

t_c = Chip thickness

t = Uncut chip thickness



Single Point Cutting Tool :

The cutting tool which is having single cutting edge, is known as single point cutting tool.

Ex: Turning tool, shaping, planing, parting tool etc.

According to American standard system, tool signature is

$$\alpha_b - \alpha_s - \gamma_e - \gamma_s - C_e - C_s - R$$

where,

α_b = Back Rake angle

α_s = Side Rake angle

γ_e = End Relief angle

γ_s = Side Relief angle

C_e = End cutting edge angle

C_s = Side cutting edge angle

R = Nose Radius

(i) Back Rake Angle (α_b)

It is the angle between the base of the tool and the base of the shank or holder and it is usually measured in a plane perpendicular to the base & parallel to length of the tool.

It affects the ability of the tool shear the work material and form the chip.

(ii) Side Rake Angle (α_s)

It is the angle between the base of the tool and the base of the shank or holder, it is usually measured in a plane perpendicular to the base and parallel to the width.

(iii) End Relief angle (γ_e)

It is the angle between the portion of end flank immediately below the end cutting edge and a

line drawn through the cutting edge perpendicular to the base, it is usually measured in a plane perpendicular to the end flank.

(iv) Side Relief Angle (γ_s)

It is the angle between the portion of the side flank immediately below the side cutting edge and a line drawn through this cutting edge perpendicular to the base.

(v) End cutting Edge angle (C_e)

The end cutting angle is the amount that the end cutting edge slopes away from the nose of the tool, so that it will clear the finish surface on the work piece.

(vi) Side Cutting Edge angle (C_s)

It is the angle which prevents interference as the tool enters the work Materials (normally 15° to 30°), larger this angle the greater the component of force tending to separate the work and tool (may induce chatter)

(vii) Nose Radius (R)

It is the curvature of the tool take it strength the tool nose and provide between surface finish. If nose radius increase, cutting force and cutting power will also increase.



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