1. (a) Find a root of the equation $x^2 - x - 1 = 0$ correct to four decimal places by the general iteration method.

OR

(a') Find the real root of $x \log_{10} x - 12 = 0$ correct to three places by Newton-Raphson method.

(b) The equation $x^2 + ax + b = 0$ has two real roots $\alpha$ and $\beta$. Show that $x_{n+1} = \frac{a x_n + b}{x_n}$ is convergent near $\alpha$ if $|\alpha| > |\beta|$ and that $x_{n+1} = \frac{b}{x_n + a}$ is convergent near $\alpha$ if $|\alpha| < |\beta|$.

(c) Solve by Gauss-Seidel method (apply three iterations)

\[ \begin{align*}
   x_1 + 2x_2 + 3x_3 &= -4 \\
   x_1 + 5x_2 + 2x_3 &= -6 \\
   4x_1 + x_3 + x_2 &= 2
\end{align*} \]

2. (a) Form the difference table for the function $f(x) = 2^x - 5$ with arguments $x = 1, 2, 4, 5$. Use this table to find the interpolating polynomial that fits the data and hence find $f'(3)$.

OR

(a) Using Lagrange's interpolation formula, find the values of $y$ when $x = 10$, from the following table:

\[ \begin{align*}
   x: & \quad 5 \quad 6 \quad 9 \quad 11 \\
   y: & \quad 12 \quad 13 \quad 14 \quad 16
\end{align*} \]

(b) The following table gives the population of a town during the last six censuses. Estimate, using suitable formula, estimate the population during the period in 1910 and 1962.

\[ \begin{align*}
   \text{Year} & \quad 1911 & \quad 1921 & \quad 1931 & \quad 1941 & \quad 1951 & \quad 1961 \\
   \text{Population in thousands} & \quad 12 & \quad 15 & \quad 20 & \quad 27 & \quad 30 & \quad 52
\end{align*} \]
(c) Prove the following with usual notations
\[ \frac{1}{2} \delta^2 + \delta \sqrt{1 + \frac{\delta^2}{4}} = \Lambda \]

3. (a) Using Taylor's series (up to four degree), solve the essential value problem
\[ \frac{dy}{dx} = x - y^2, \quad y(0) = 1 \text{ at } x = 0.1. \]

OR

(a') Solve the following initial value problem by Runge-Kutta method of 4th order and find \( y(0.2) \) in one step.
\[ \frac{dy}{dx} = x - 0.1y^2, \quad y(0) = 0, \quad 0 \leq x \leq 0.2 \]

(b) Solve by finite difference method, the boundary value problem:
\[ \frac{d^2y}{dx^2} + y + 1 = 0, \quad y(0) = -1, \quad y(1) = 0. \]
Take \( h = \frac{1}{4} \).

4. (a) Solve the following linear programming problem graphically.
Max. \( Z = 5x_1 + 3x_2 \)
Subject to constraints:
\[ \begin{align*}
3x_1 + 5x_2 & \leq 15; \\
5x_1 + 2x_2 & \leq 10; \\
2x_1 + x_2 & \geq 4 \\
x_1, x_2, x_3 & \geq 0
\end{align*} \]

OR

(a') Construct the dual of the following linear programming problem
Min. \( Z = -1250x_1 + 1000x_2 + 900x_3 + 150x_4 \)
Subject to constraints:
\[ \begin{align*}
2x_1 + 2x_2 + 2x_3 & \geq 50 \\
x_1 + 5x_2 + 3x_3 + x_4 & \geq 100 \\
x_1, x_2, x_3, x_4 & \geq 0
\end{align*} \]
and then solve the problem graphically.

(b) Solve by Simplex method the linear programming problem:
Max. \( Z = x_1 + 2x_2 + x_3 \)
Subject to:
\[ \begin{align*}
2x_1 + x_2 - x_3 & \leq 2 \\
-2x_1 + x_2 - 5x_3 & \geq -6 \\
4x_1 + x_2 + x_3 & \leq 6 \end{align*} \]
\( x_1, x_2, x_3 \geq 0 \)
2015-16
B.TECH. (AUTUMN SEMESTER) EXAMINATION
Department of Electrical Engineering
Control Engineering (EE-305)
[For Mechanical Engg. Students]

Maximum Marks: 60
Credits: 04
Duration: Three Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

1(a) Explain the working of an AC servomotor and also derive its transfer function.

1(b) For the linear translational system shown in figure 1, find out the transfer function $X_1(s)/F(s)$.

![Figure 1](image)

What are the conditions for which the transfer function of a system can be obtained?

OR

1'(a) With the help of a suitable diagram and expressions, explain how a synchro transmitter-receiver pair can be used as an error detector in a feedback control system.

Also derive its transfer function.

1'(b) Explain the effects of feedback on:
   i) Gain of the system.
   ii) Sensitivity to the changes in system parameters.
   iii) Stability of the system.

2(a) Signal flow graph of a system is shown in figure 2. Find out the transfer function $C(s)/R(s)$ of the system using Mason's Gain Formula.

![Figure 2](image)

Contd......2.
2(b) Find out the transfer function \( C(s)/R(s) \) of the system shown in figure 3 using block diagram reduction technique.

3(a) A system is described by the following differential equation:

\[
\frac{d^3 x}{dt^3} + 3 \frac{d^2 x}{dt^2} + 4 \frac{dx}{dt} + 4x = u_1 + 3u_2 + 4u_3
\]

and output equations are

\[
\begin{align*}
y_1 &= \frac{dx}{dt} + 3u_4 \\
y_2 &= \frac{d^2 x}{dt^2} + 4u_2 + u_3
\end{align*}
\]

Represent the system in state space form.

3(b) Obtain the response of the system whose state space equations are given below.

\[
\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u(t),
\]

and

\[
y(t) = \begin{bmatrix} 2 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}
\]

where, \( u(t) \) is a unit step input occurring at \( t=0 \), and \( x(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \)

4(a) Consider a unity feedback control system with forward path gain:

\[
G(s) = \frac{\omega_n^2}{s(s + 2\zeta\omega_n)}
\]

Determine the value of \( \zeta \) and \( \omega_n \) so that the system responds to a step input with approximately 5% overshoot and with a settling time of 2 sec.

4(b) Sketch the root locus plot for the system whose open-loop transfer function is given below. Also, determine the value of \( K \) for sustained oscillations in the output.

\[
G(s)H(s) = \frac{K}{s(s + 2)(s + 4)}
\]

OR

4'(a) The closed loop transfer function of a second order system is given by:

\[
\begin{align*}
\frac{C(s)}{R(s)} &= \frac{25}{s^2 + 6s + 25}
\end{align*}
\]

Determine rise time, peak time, maximum overshoot, and settling time of the system for unit step input. Also, find the expression of output, \( c(t) \) for unit step input.

Contd... 3.
4'(b) Sketch the root locus plot for the system when open-loop transfer function is given by:

\[ G(s)H(s) = \frac{K}{s(s + 4)(s^2 + 4s + 13)} \]

5(a) The forward path transfer function of a unity feedback control system is given below. Find the resonant peak, resonant frequency and band-width of the closed loop system.

\[ G(s)H(s) = \frac{100}{s(s + 6.54)} \]

5(b) Construct Bode plot of the system whose open-loop transfer is given below and determine (a) gain margin (b) phase margin and (c) closed-loop stability.

\[ G(s)H(s) = \frac{2(s + 0.25)}{s^2(s + 1)(s + 0.5)} \]

5'(a) i) A system has the characteristic equation:

\[ s^6 + 2s^5 + 8s^4 + 12s^3 + 20s^2 + 16s + 16 = 0 \]

Using Routh-Hurwitz criteria find out whether the system is stable, unstable or marginally stable.

ii) If for a system the Routh-Hurwitz table has a row with all-zero elements. What are the various possibilities for the location of the system poles?

5'(b) What are Proportional, Derivative and Integral Controllers? Explain in detail their effects on the overall response of a system.
Question

I(a) With a neat sketch explain the inversion of double slider crank mechanism. Name all the inversions of double slider crank mechanism.

I(b) What do you mean by straight line mechanism? Name the different mechanisms which are used for exact straight line motion.

2 The crank of a slider crank mechanism is 150 mm and the connecting rod is 600 mm long. The crank makes 300 rpm in the clockwise direction. When the crank has turned 45° from the inner dead centre position, determine:

(i) Velocity of slider C, (ii) Angular velocity of connecting rod.

OR

2' The crank of a slider crank mechanism is 200 mm and the connecting rod is 800 mm long. The crank makes 480 rpm in the clockwise direction. When the crank has turned 45° from the inner dead centre position, determine the angular acceleration of the connecting rod.
3. Determine the lengths of all the four links in a four bar chain for the length of the smallest being 10 cm to generate \( y = \log_{10} x \) in the interval \( 1 \leq x \leq 10 \) for three accuracy points. The range of angles of input link and output link are \( 45^\circ \leq \Theta \leq 105^\circ \) and \( 135^\circ < \phi < 225^\circ \).

4(a) Calculate:
(i) Length of path of contact. 
(ii) Area of contact and 
(iii) the contact ratio when a pinion having 23 teeth drives a gear having 57 teeth. The profile of the gear is involute with pressure angle 20°, module 8 mm and addendum equal to one module.

4(a') Two mating gears having 50 and 13 involute teeth of module 10 mm and 20° pressure angle. The addendum is one module. Does the interference occur? If it occurs, to what value should the pressure angle be changed to eliminate interference?

4(b) Two parallel shafts are connected with the help of two gears, one on each shaft. The number of teeth on gear is 38 and the speed of the shaft is 420 rpm. If the speed ratio is equal to 3 and circular pitch of the gears is 25 mm, then find (i) the number of teeth and speed of the other gear, (ii) centre distance between two shafts.

5. The following data is related to a symmetrical circular arc cam operating a flat faced follower:
Least radius of the cam = 27.5 mm, total lift = 12.5 mm, angle of lift = 55°,
nose radius = 3 mm, speed of cam = 600 rpm.
Find:
(i) distance between cam centre and nose centre,
(ii) radius of circular flank, and
(iii) angle of contact on the circular flank.
Q.No. | Question | M.M.
--- | --- | ---
1.(a) | What are different types of welded joints? Illustrate with neat sketches. | [04]
1.(b) | An eccentrically loaded bracket is welded to its support as shown in Fig (1). Give the complete design procedure to determine the maximum resultant stress in the welded connection. | [04]
1.(c) | Why testing of models are important in Design? State and explain the division of design projects. | [04]
2.(a) | Explain cone clutch with the help of neat sketch. Derive the expressions for the actuating force $F$ and the frictional torque $T$, using both uniform pressure and uniform wear methods of solution. | [06]
2.(b) | A multi plate disc clutch transmits 55 kW of power at 1800 rpm. The coefficient of friction for the frictional surface is 0.1. Axial intensity of pressure should not exceed 160 kN/m². The internal radius is 80 mm and is 0.7 times of the external radius. Find the number of plates needed to transmit the required torque. | [06]

**OR**

2' | The brake shown in Fig (2) is 300 mm in diameter and is actuated by a mechanism that exerts the equal force $F$ on each shoe. The shoes are identical and have a face width of 32 mm. The lining is a moulded asbestos having a coefficient of friction of 0.32 and a pressure limitation of 1000 kPa. Estimate the maximum

(i) actuating force $F$
(ii) braking capacity

*Contd...*
3.(a) Derive the relations of bending stress and deflection for a helical torsion spring.

3.(b) A 2.24 mm BS5216 grade 4 compression spring has an outside diameter of 14.3 mm, a free length of 105 mm, 21 active coils, both ends are squared and ground. The spring is unopened. The spring to be assembled has a preload of 45 N and will operate to a maximum load of 225 N during use. Determine the fatigue factor of safety guarding against a failure based on a life of $50 \times 10^3$ cycles and 99% reliability.

The following equation for the fatigue strength may be used:

$$S_f = 10^8 \times N^b$$

Where, $b = - (1 / 3) \log \left(\frac{0.8 \, S_{ou}}{S_{m}}\right)$ and, $c = \log \left(\frac{(0.8 \, S_{ou})^2}{S_{nc}}\right)$

The data are given as:

- Constant related to strength intercept on log-log S-N diagram, $A = 2160 \, \text{MPa-mm}^m$,
- Slope of line on the plot, $m = 0.145$,
- Endurance strength in shear for unopened spring specimen, $S_{ou} = 310 \, \text{MPa}$,
- Reliability factor, $k_e = 0.814$ and
- Notch sensitivity of the spring steel is close to unity.

OR

3.(b) A truck suspension spring has 12 number of leaves, two of which are full length leaves. The spring supports are 1.05 m apart and the central band is 85 mm wide. The central load is to be 5.4 kN with a permissible stress of 280 MPa. The ratio of the total depth to the width of the spring is 3. The modulus of elasticity of the leaf spring material is 210 GPa. Determine:

- (i) width and thickness of the steel spring leaves
- (ii) deflection of the spring.

4(a) State the assumptions and derive the Striebeck's equation for static load capacity of a rolling element bearing.

4(b) Following data is given for a 360° hydrodynamic bearing:

- Radial load = 15 kN,
- Journal speed = 1450 rpm,
- Bearing pressure = 1000 Kpa,
- Clearance ratio = 700 and viscosity of lubricant = 30 mPa-sec,
- Density of oil is 861 Kg/m³ and average value of specific heat of the oil is taken as 1760 J/kg °C.

Assuming that the total heat generated in the bearing is carried by the total oil flow.
in the bearing and \((d/d - 1)\), calculate dimensions of the bearing, coefficient of friction, total flow of oil, and temperature rise.

**OR**

4(b') A transmission shaft rotating at 700 rpm and transmitting power from pulley P to spur gear G shown in Fig (3). The belt tensions and gear tooth forces are as follows: \(P_1 = 490\text{N}, P_2 = 160\text{N}, P_t = 500\text{N}, P_r = 180\text{N}\). The weight of the pulley is 100N. The diameter of the shaft at bearings \(B_1\) and \(B_2\) is 10mm and 20mm respectively. The load factor is 2.5 and expected life for 90% of the bearing is 8000hr. Select single row deep groove ball bearings at \(B_1\) and \(B_2\).

5.(a) Draw the diagram showing tooth force acting on a right hand helical gear and derive the expressions for the normal and tangential components of the force.

**OR**

5.(a') Draw and explain stable hydrodynamic lubrication diagram. Write five properties of a good lubricant.

5.(b) Using Buckingham approach, design a pair of spur gears to transmit 25kW power from a pinion running at 900rpm to a gear running at 300rpm. Design the gears so that they can last for \(10^8\) cycles. Assume 20° full depth involute spur gear for the system. Motor shaft diameter is 30mm. Take permissible bending strength and hardness of material for pinion as 542 MPa, 223 Bhn and for gear as 487 MPa, 215 Bhn. Lewis form factor for pinion and gear may be taken suitably i.e. between 0.25 to 0.50. The coefficient \(C\) is 150. Also check for tooth bending failure.

continued...
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*Dimensions and static and dynamic load at specified direction are given on bell housing.*

---

*Cont'd...*
Q. No. 1

(a) Write the first law of thermodynamics for a chemical reaction occurring in control volume and control mass. Explain the procedure for obtaining the adiabatic flame temperature in both the cases.

(b) A liquid blend of 80% n-octane (C₈H₁₈) and 20% ethanol (C₂H₅OH) is burned with 400% excess air at 0.1 MPa and 25°C in a steady flow process. Determine the adiabatic flame temperature, Air ratio on mass and mole basis.

OR

What is meant by minimization of Gibb's energy. What is its advantage when considering chemical reactions. A steady state combustion chamber is supplied with CO at (210 K, 0.35 m³/min) and O₂ at (298 K and 0.3 kg/min). The combustion products (CO₂, CO₂ and O₂) leave the chamber at 2000 K. Pressure everywhere is equal to 110 kPa. The equilibrium equation among CO, CO₂ and O₂ can be expressed as: CO₂ ⇌ CO + 1/2 O₂. Determine O₂/Fuel ratio and value of K_p. Write K_p in terms of number of moles and pressure P. Suggest a procedure for evaluating rate of heat transfer from the combustion chamber. Take Gibbs function of formation $G_f$ (kJ/kmol) for CO, O₂ and CO₂ as: -285.948, 0 and -396.410 respectively.

2. For a reheat-regenerative Rankine cycle, steam enters the turbine at 10 MPa, 500°C. Some steam is bled off at 1 MPa for constant pressure reheating and returned to the turbine at 500°C. After that, a fraction ‘y’ is extracted from the turbine at 0.6 MPa and taken to an open feed water heater (OFWH), which is also at 0.6 MPa. The
liquid leaving the OFWH is assumed as saturated liquid at the same pressure. The remaining stream ‘1-y’ is then expanded in the turbine to the condenser pressure of 15 kPa. The feedwater pump placed after the condenser raises the pressure to 0.6MPa and delivers it to the OFWH, whereas the second pump deployed after the OFWH feeds the water to the boiler at 10 MPa. Assuming isentropic turbine and pump efficiencies respectively as 100%, calculate the heat and work interactions, net work and thermal efficiency of the plant. Draw the plant layout and show the resulting cycle on a T-s diagram.

OR

2(a) What kind of boiler is employed in a supercritical power plant. Explain in brief its principle of operation. Draw layout of an ideal, double reheat supercritical Rankine cycle power plant (with no feedwater heating) together with T-s diagram.

(b) Mention the advantages and drawbacks of using mercury in the binary Hg-steam cycle. Draw the cycle on a T-s plot explaining the various processes involved.

3 Using relevant relations, draw the curves for property variation with area change for sub and supersonic flows, when dp is taken as positive. Briefly discuss the difference in flow characteristics through a con-div nozzle when the fluid is (i) an ideal gas, (ii) steam.

4(a) What do you understand by compounding of steam turbine?

(b) A single-row impulse turbine has blades whose inlet angle is 40° and exit angle 37°. The mean blade speed is 230 m/s and the nozzles are inclined at an angle of 27° to the plane of the rotation of the blades. There is a 10% loss of relative velocity due to friction in the blades. The turbine uses 550 kg/h of steam. Determine (i) the nozzle velocity of the steam, (ii) the absolute velocity of the steam at exit, (iii) the power output of the turbine, (iv) the end thrust on the turbine and (v) the diagram efficiency.

3(a) Write down the energy balance for a mixing and non-mixing type of condenser.

(b) In an induced type of mechanical cooling tower, water from the condenser enters the tower at 44°C and 5.5 litres/s. The induced draft fan injects 9m³/s of outside air at 18°C and 60% RH and air leaving the tower is assumed saturated at 26°C. If the power consumed is 4.75 kW, calculate (i) the make up water rate in kg/s, (ii) the enthalpy of the cooled water leaving the cooling tower and its temperature.
1(a) Write the significance of Fourier number and Biot number.
1(b) Discuss the situation when installation of fins will not increase the heat transfer rate.
1(c) The temperature of hot gas flowing through a pipe is measured by a mercury thermometer immersed in oil filled steel well. The thermometer reads the temperature at the end of the well which is lower than the gas temperature due to conduction of heat along the well. The temperature of the pipe wall is 60 °C and the thermometer reads 120°C. The well is 10 cm long and the thickness of well wall is 2 mm. The heat transfer coefficient between the gas and thermometer well is 100 W/m²K and thermal conductivity of steel is 40 W/mK. Show the arrangement of the thermometer well and find the percentage error in the temperature measurement.

OR

1' Name some of the engineering systems in which heat is generated internally. Derive the expressions for temperature distribution and the temperature at the centre of a solid sphere with uniform heat generation and 1-D steady state heat conduction.
A solid sphere of radius 50 mm and thermal conductivity 20 W/mK, is heated uniformly at the rate of $2 \times 10^5$ W/m³, and the heat is dissipated by convection to ambient air at 25°C with heat transfer coefficient of 100 W/m²K. Determine the steady state temperature at the centre and outer surface of the solid.

2(a) With suitable diagram and expressions, explain the method for obtaining heat transfer coefficient. Giving examples, describe the relevance of Prandtl number in the formation of velocity and temperature boundary layers during forced convection.
2(b) With suitable assumptions and diagram, obtain heat transfer equations for laminar flow of liquid metal over a flat plate.

OR

2' Describe filmwise and dropwise condensation. Obtain the relation for heat transfer coefficient for laminar film condensation over a vertical plane surface. A vertical plate 0.5m height and 0.2m width, maintained at 50°C, is exposed to the saturated steam at

Contd...2.
100°C. Calculate the average heat transfer coefficient and rate of steam condensed. Properties of saturated steam at 100 °C are \( \mu = 0.396 \text{ kg/m}^2 \cdot \text{s} \), \( h_f = 2237 \text{ kJ/kg} \) and that of the saturated water at 75°C are \( p = 975 \text{ kg/m}^3 \), \( k = 0.668 \text{ W/mK} \), \( \mu = 3.75 \times 10^{-4} \text{ kg/ms} \).

3 Using the electrical network method, obtain the equations for heat transfer between two infinite parallel planes with a radiation shield in between them. Two square plates, each of 5 m² area are separated by a gap of 6 mm. One plate, whose surface emissivity is 0.7, is at a temperature of 627°C. The other plate has surface emissivity of 0.95 and a temperature of 27°C. Assuming the plates to be much larger than the gap, calculate the net radiation exchange between the plates. If a thin polished metal sheet of surface emissivity 0.15 on both sides is interposed between the plates, calculate the steady-state temperature of the metal sheet. Calculate how many times the heat loss by radiation will be reduced.

OR

3'(a) Differentiate between solar radiation and thermal radiation. Why glass cover is used in solar collectors? What is a radiation shield? What are its engineering applications?

3'(b) Two parallel plates of size 1 m x 1 m are located in a very large room, the walls of which are maintained at 27°C. The plates are maintained at 900°C and 400°C and their emissivities are 0.2 and 0.5, respectively. If the plates exchange heat between themselves and with the room, find the net heat transfer between the plates and the heat received by the room. The radiation shape factor between the plates may be taken as 0.415.

4 Explain LMTD correction factor. Derive the expression for effectiveness of a counter flow heat exchanger in terms NTU and heat capacity ratio. A heat exchanger is employed to cool 9000 kg/h of oil \( C = 1.9 \text{ kJ/kgK} \) from 180°C by the use of water \( C = 4.184 \text{ kJ/kgK} \) flowing at the rate of 4320 kg/h and entering at 25°C. The area of the heat exchanger is 16 m² and the overall heat transfer coefficient is expected to be 285 W/m². Make calculations for the exit temperatures of water and oil considering a counter flow arrangement.

5 With practical examples, define and differentiate between diffusion and convective mass transfers. Show that the diffusion mass transfer is analogous to the conduction heat transfer and Newton’s law of viscosity. Describe Fick’s law of diffusion for perfect gases. Obtain the expression for total mass transfer during isothermal evaporation from a surface of water in a deep tank and subsequent diffusion through a stagnant air layer.
2015-16
B.TECH. (AUTUMN SEMESTER) EXAMINATION
(MECHANICAL ENGINEERING)
L.C. ENGINES
ME-324

Maximum Marks: 69
Credits: 04
Duration: Three Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No.  Question  M.M.
1(a)  Describe with suitable sketches, the different scavenging systems of 2-stroke  [04]
      engines.
1(b)  Discuss the type of mixture requirement for steady state operation of SI engines.
      Why does the engine require rich mixture during idling and power ranges?  [04]
1(c)  What is the significance of supercharging in IC engines? Give the schematic  [04]
      diagrams for various supercharging and turbo-charging systems in IC engines.
2(a)  Differentiate between Fuel-Air cycle and Actual cycle in IC engines.  [06]
2(b)  If the specific heats of a gas are expressed as \(C_p = a + kT \) \& \(C_v = b + kT \), Where  [06]
      \(a, b, \) and \(k\) are arbitrary constants. Prove that the law of adiabatic expansion is
      given by  \(p^n e^{kT} = \text{const.}\)

OR

2'(a)  Discuss the advantages of overhead cam over pushrod in IC engines.  [04]
2'(b)  An oil engine working on dual combustion cycle, has a compression ratio of 13:1.  [08]
      The heat supplied per kg of air is 2000 kJ, half of which is supplied at constant
      volume and other half at constant pressure. If the temperature and pressure at
      the beginning of compression are 100 °C and 1 bar respectively. Find (i) the maximum
      pressure in the cycle and (ii) the percentage of stroke when cut-off occurs. Assume
      \(\gamma = 1.4\), \(R = 0.287 \text{ kJ/kgK}\) and \(C_v = 0.709 + 0.000028 T\)  \text{ kJ/kgK}

Contd....2.
3 Explain the normal combustion phenomena in CI engines by specifying various stages of combustion. Also discuss the variables which affect the delay period in these engines.

OR

3' Describe the commonly used CI engine combustion chambers along with their merits and demerits.

The entire output of a supercharged 4-stroke cycle oil engine is used to drive an air compressor. The air enters the compressor at 20 °C and is delivered to a cooler which removes heat at the rate of 1335 kJ/min. The air leaves the cooler at 62 °C and 1.72 bar. Part of this air flow is used to supercharge the engine which has a volumetric efficiency of 0.70 based on induction manifold conditions of 62 °C and 1.72 bar. The engine which has six cylinders of 90 mm bore and 100 mm stroke runs at 2000 rpm and delivers an output torque of 150 Nm. The mechanical efficiency of the engine is 0.75. Determine (i) the engine indicated mean effective pressure (ii) the air consumption in kg/min (iii) air flow into compressor in kg/min.

4(a) Explain the advantages of Regeneration in a Gas Turbine Plant. Obtain the expression for Thermal efficiency of such a plant taking into account all component efficiencies.

4(b) A closed cycle gas turbine uses helium as the working substance. The gas enters the compressor at 4 bar & 320 K and discharges at 16 bar & 590 K. It then enters a regenerator of effectiveness 70%. From the regenerator, it goes to another heat exchanger where further heat is added from combustion gases. The helium then enters the turbine at 15.5 bar & 1400 K and leaves the turbine at 4.2 bar & 860 K to enter to the regenerator. From the regenerator, it goes to the compressor through a cooler where heat is rejected before compression. Determine, (i) the compressor and turbine efficiencies (ii) the thermal efficiency of the cycle (iii) the heat rejected in the cooler before compression (iv) the helium flow rate for a net power output of 100 MW. Take C_p and γ for helium as 5.2 kJ/kg K and 1.67 respectively.

OR

4'(a) With the help of neat sketches, describe the working of a Turbofan engine.

Contd... 3.
4(b) A jet engine in which all compressions and expansions are isentropic, is operating at an altitude where the entrance pressure is 83 kPa. And the entrance temperature is 230 K. The aircraft is moving at a velocity of 305 m/s. Fuel is added so the maximum temperature is 1400 K and the compressor discharge pressure is 480 kPa. Neglect the mass of the fuel, assuming air as the substance throughout. Determine (a) the exit velocity of the combustion gas from the engine (b) the specific thrust and (c) propulsive efficiency.

5(a) What are the desirable qualities of SI engine fuel? Discuss the significance of ASTM distillation curve by taking into account all the three ranges of the volatility of gasoline.

5(b) What do you understand by 'Octane Number'? Describe the procedure and standard test conditions for obtaining the above number for a given fuel. Also, explain the term 'Sensitivity'.
Maximum Marks: 60    Credits: 04    Duration: Three Hours

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No.    Question

1(a) Explain the mechanism for the formation of the following type of chips.
   i) Continuous chips with BUE
   ii) Continuous chips without BUE
   iii) Discontinuous chips

1(b) During orthogonal machining with a cutting tool having a 10° rake angle, the results obtained are:

   Uncut chip thickness = 0.30 mm; Chip thickness = 0.80 mm; Width of the workpiece under cutting = 2.8 mm; Cutting force = 1000 N; Thrust force = 500 N. Determine:

   i) Shear plane angle
   ii) Magnitude of the shear strain
   iii) Coefficient of friction between the tool and the chip
   iv) Ultimate shear stress of the work material

2(a) Determine the three components of the machining force when shaping a cast iron block with depth of cut = 5 mm, feed = 0.30 mm/stroke, normal rake angle = 12°, principal cutting edge angle = 32°, coefficient of friction between chip and tool = 0.7 and ultimate shear stress of cast iron = 350 N/mm².

2(b) Explain the following with respect to Grinding wheels:

   i) Grain size
ii) Grade
iii) Structure

OR

2'(a) Estimate the power required during the upmilling of a mild steel block of 25 mm width using a straight slot milling cutter with 10 teeth, 75 mm diameter, and 10° radial rake angle. The feed velocity of the table is 120 mm/min., the cutter rotates at 60 rpm, and the depth of cut is 6 mm. The coefficient of friction at the work face and the shear stress of the work material are 0.5 and 400 N/mm².

2'(b) Discuss the following processes:
   i) Surface rolling
   ii) Shot peening
   iii) Case hardening

3(a) What are the distinctive requirements of cutting tools used in CNC machines?
3(b) What is a part programming? Discuss the steps in writing a part programme.

3'(b) Give G-M codes for the following:
   i) Linear interpolation
   ii) Incremental dimensioning
   iii) Spindle on (anti-clockwise)
   iv) Feed rate
   v) Circular interpolation (clockwise)
   vi) Coolant on
   vii) External thread cutting
   viii) Circular interpolation (anti-clockwise)

OR

3' Explain any TWO of the following:
   i) Electric Discharge machining process
   ii) Electro-Chemical machining process
   iii) Plasma-Arc machining process

4 Write short notes on the following:
   i) Tolerances
   ii) Interchangeability
   iii) Selective assembly

OR

4'(a) Distinguish and sketch the limits of tolerances and allowances for a 35 mm shaft and hole pair designated H7. The basic size lies in the range of 30-50 mm. The
tolerances for grade 8 and 9 are 25 and 40, respectively. The fundamental deviation for the "d" shaft is -16D^0.41.

4'(b) Distinguish between 'line standard' and 'end standard'. How are end standard derived from line standard?

4'(c) What are limit gauges? Describe the Taylor's principle of GO and NO GO gauges.

5 Attempt any TWO of the following questions.
   i) Explain with a neat sketch any type of comparators you know and show clearly the advantages of magnifications adopted.
   ii) Describe the use of optical flats and monochromatic light for dimensional comparison and testing flatness of surfaces.
   iii) Explain what is understood by the term 'Alignment test' of a machine tool. Describe any method of testing centre lathe for accuracy of facing.
1(a) A uniform stream of flow (velocity U) is passed over a fixed cylinder and a rotating cylinder (of same radius a) with rotation ‘o’. Using inviscid flow theory determine, in which case lift will be generated and how much.

1(b) For the figure shown below, find the resultant velocity vector induced at point A due to the combination of uniform stream, vortex and a line source.

1(c) Consider the superposition of a uniform flow U, a doublet of strength ‘k’ and a vortex of rotation ‘P’ at the origin. Obtain the stream function, potential function and determine the locations of stagnation points. By applying Bernoulli’s equation obtain the pressure.

2(a) Air enters a constant-area duct at $p_1 = 90$ kPa, $V_1 = 520$ m/s, and $T_1 = 550$°C. It is
cooled with negligible friction until it exists at $p_2 = 160$ kPa. Estimate (a) $V_2$, (b) $T_2$, and (c) the total amount of cooling in kJ/kg. \( C_p = 1.005 \text{ kJ/} \text{kg K} \), \( \gamma = 1.4 \)

2(b) A bend in the bottom of a supersonic duct flow induces a shock wave which reflects from the upper wall, as in Figure. Compute the Mach number and pressure in region 3.

2'(a) Air flows at Mach number of 1.8 with a pressure of 90 kPa and a temperature of 15°C down a wide channel, as shown in Figure. The upper wall of this channel turns through an angle of 5° “away from the flow” leading to the generation of an expansion wave. Find the pressure, Mach number, and temperature behind this expansion wave.

2'(b) A normal shock occurs at a point in an air flow where the pressure is 30 kPa and temperature is -30°C. If the pressure ratio across this shock wave is 2.7, find the pressure and temperature downstream (i.e., after) this normal shock wave and the velocities both upstream of and downstream of the shock wave. Also find the change in the stagnation pressure across the shock.

3(a) Why it is not possible to predict the turbulent flow in detail experimentally as well as numerically. What are the different sources of disturbances faced in experiments of turbulent flow.

Cont.....3.
The parameter $\alpha$ is a dimensionless pressure gradient given as

$$\alpha = \frac{\left(\frac{\partial p}{\partial x}\right)}{\left(\frac{\partial \mu}{\partial x}\right)} \frac{H^2}{\mu U}.$$  

5(a) Using the fact that viscous effects propagate across streamlines in time $t$ through a distance $\sim \sqrt{\nu t}$, show that for a steady viscous flow over a flat surface, the local thickness of the viscous layer $\delta(x)$ at a distance 'x' from the leading edge is approximately given as $\delta \approx k(Re_x)^{-1/2}$ where $Re_x = U_x \nu$. $U_x$ is the scale of velocity along the surface. Hence show that a thin boundary layer is formed when $Re_x \gg 1.0$.

5(b) Consider the boundary layer equations for an incompressible, 2D, steady boundary layer flow over a flat surface ($y = 0$):

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \nu \frac{\partial^2 u}{\partial y^2}$$

(i) Apply the limit $y \to 0$ to the continuity equation and obtain the limiting result. Hence show that near the surface, $v \sim y^2$.

(ii) Apply the limit $y \to 0$ to the momentum equation to show that:

$$\left(\frac{\partial F}{\partial x}\right) = \frac{\partial p}{\partial x}$$

(iii) Using the result obtained in (ii) show the typical u-profiles across the boundary layer for accelerating, uniform and retarding outer flow. Under what conditions the boundary layer may undergo 'separation'.

5(b') Show that self-similar solutions of the type $\frac{u(x, y)}{U(x)} = f(\eta), \eta = \frac{y}{g(x)}$ can be obtained for incompressible 2D, steady, boundary layer flow subjected to a non-uniform outer flow $U(x)$. Use the stream function $\psi = U(x)g(x)f(\eta)$ to show that the function $f(\eta)$ satisfies the ordinary differential equation:

$$\frac{d^2 f}{d\eta^2} = \frac{\dot{\psi}}{\psi}.$$
\[ f'' + \left( \frac{U(x)}{v} g' \right) f' + \frac{g^2}{v} U'(1 + f f'' - f'^2) = 0 \]

Thus, obtain the necessary conditions for existence of self similar solutions. Further, show that for uniform outer flow \( U(x) = U_o \), the scaling function \( g(x) \) is given as, \( g(x) = (\text{const}) \sqrt{\frac{2v_x}{U_o}} \).

5(e) Consider an approximate u-velocity profile across the boundary layer over a flat surface subjected to an uniform outer flow \( U_o \) as,

\[
\frac{u}{U_o} = A + B_1 \eta + C \eta^2 + D \eta^3, \quad \eta < 1.0
\]

\[
\frac{u}{U_o} = 1.0, \quad \eta > 1.0
\]

In the above profile, \( \eta = y / \delta \). Apply the appropriate boundary conditions to obtain the constants \( A, B, C \) and \( D \). Also obtain the displacement thickness for this profile in terms of \( \delta \).
1(a) Do you agree that there is a connection between workplace flexibility and productivity? Support your answer citing a suitable example. Why is it difficult to measure productivity in a service industry?

A production manager was going through the production and machine hour consumption report of the last three months.

<table>
<thead>
<tr>
<th>Month</th>
<th>Machine hours</th>
<th>Units produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 2015</td>
<td>90000</td>
<td>99000</td>
</tr>
<tr>
<td>October 2015</td>
<td>100000</td>
<td>100000</td>
</tr>
<tr>
<td>November 2015</td>
<td>150000</td>
<td>135000</td>
</tr>
</tbody>
</table>

The report clearly showed that there had been an increase in production with a simultaneous increase in machine hour consumption. The manager was not sure whether it really indicated a rise in productivity or merely increase in production. How can you answer his problem?

1(b) Explain the process used for the design of a product.

OR

1'(b) What do you understand by the product-process matrix in a production system? Explain.

1(c) Write the procedure used for making value engineering studies.

The value of a function is defined as the relationship of cost to performance:

\[ \text{Value}^{\text{max}} = \frac{\text{Performance}^{\text{max}}}{\text{Cost}^{\text{min}}} \]

Giving a suitable example, explain the relationship.

2(a) What is the concept of Group Technology? Elaborate methods of identifying part families?

You want to balance an assembly line. How would you deal with a situation where one worker although trying hard, is 20% slower than the rest of the workers?
2(b) The following tasks must be performed on an assembly line in the sequence and time specified in the table.

<table>
<thead>
<tr>
<th>Task</th>
<th>Task time (min)</th>
<th>Task that must precede</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.2</td>
<td>B, C, D</td>
</tr>
<tr>
<td>B</td>
<td>3.4</td>
<td>E</td>
</tr>
<tr>
<td>C</td>
<td>1.7</td>
<td>E</td>
</tr>
<tr>
<td>D</td>
<td>4.1</td>
<td>F</td>
</tr>
<tr>
<td>E</td>
<td>2.7</td>
<td>F</td>
</tr>
<tr>
<td>F</td>
<td>3.3</td>
<td>G</td>
</tr>
<tr>
<td>G</td>
<td>2.6</td>
<td></td>
</tr>
</tbody>
</table>

(i) Draw the schematic diagram.
(ii) What is the theoretical minimum number of stations required to meet a demand of 100 units/day when the time available/shift is 450 minutes?
(iii) What is the efficiency of the balanced line?

OR

2(a) Explain the difference between Factor rating method and Weighted Factor rating method of selecting a new facility location. Which will you prefer?

2(b) The data for a certain project has been presented below:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Predecessor</th>
<th>Optimistic time (day)</th>
<th>Most likely time (day)</th>
<th>Pessimistic time (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>4</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>3</td>
<td>4.5</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>A</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>C</td>
<td>6</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>E</td>
<td>B</td>
<td>4</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>F</td>
<td>C</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>G</td>
<td>D, E</td>
<td>15</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>H</td>
<td>B</td>
<td>5</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>I</td>
<td>H</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>J</td>
<td>C, I</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

(i) Draw the precedence diagram.
(ii) Using PERT calculate project completion time with in 150 limit.

3 Answer any two of the followings:

(i) What is 'scheduling system'? How it helps in planning the industrial environment?
(ii) Set a detailed time standard for a complete product of your own choice. Use numerical example.

(ii) Discuss the role of 'environmental factors' in the 'Ergonomic Design' of an automated manufacturing system.

4(a) What is material requirement planning (MRP)? Using numerical example, explain how a detailed MRP schedule is established?

4(b) Describe any four wastes suggested by Shigeo Shingo to implement JIT system of manufacturing. Use practical examples. OR

4* ABC company purchases 22000 units of a component in one year. The purchase price in dollars depends on the order quantity in the following way:

<table>
<thead>
<tr>
<th>Order Quantity</th>
<th>Less than 1000</th>
<th>1001-2000</th>
<th>2001-4000</th>
<th>4001-5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase Price Per Unit</td>
<td>108</td>
<td>103</td>
<td>97</td>
<td>92</td>
</tr>
</tbody>
</table>

The ordering cost per order is $300 if the order quantity is less than 1500 units; it becomes $500 if the order quantity is between 1500 and 3000 units; it becomes $800 if the order quantity is more than 3000 units. The annual holding charges per unit are 25% of the unit purchase price. Find the Economic Order Quantity (EOQ) and the minimum total cost.

5(a) What are the basic tools of quality control? Explain any one. OR

5'(a) What is the difference between Acceptable Quality Level and (AQL) and Lot Tolerance Percent Defective (LTPD).

5(b) An SPC study was undertaken to determine whether the process was in statistical control. During a period of 10 weeks, the weekly number of deliveries not meeting the target time was monitored as has been presented below:

<table>
<thead>
<tr>
<th>week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>deliveries</td>
<td>800</td>
<td>845</td>
<td>830</td>
<td>780</td>
<td>770</td>
<td>880</td>
<td>875</td>
<td>780</td>
<td>700</td>
<td>920</td>
</tr>
<tr>
<td>deliveries not meeting target</td>
<td>96</td>
<td>106</td>
<td>99</td>
<td>79</td>
<td>76</td>
<td>66</td>
<td>61</td>
<td>77</td>
<td>56</td>
<td>120</td>
</tr>
</tbody>
</table>

Determine UCL and LCL for the process.

5(c) Apply gradient search procedure to solve the following non-linear programming problem. Select an error tolerance to perform only three iterations.

Maximize \( f(X) = 8X_1 - X_1^2 - 12X_2 - 2X_2^2 + 2X_1X_2 \)