2014-15
B.TECH (WINTER SEMESTER) EXAMINATION
MECHANICAL ENGINEERING
PROCESSING OF PLASTICS, POLYMERS & CERAMICS (DE)
ME-407
Credits: 04 Duration: Three Hours

Maximum Marks: 60
Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No. Question M.M.
1(a) What are the major differences between the properties of plastics and of metals? (04)
1(b) What properties are influenced by the degree of polymerization? (04)
1(c) Describe the methods by which optical properties of polymers can be altered. (04)
2 Write a detailed description on application of polymeric materials in the areas given below particularly emphasizing on recent trends:
   I. Automobile applications
   II. Aerospace applications
   III. Medical applications
   IV. Corrosion prevention and control
   (12)

OR

2' Explain the following:
   I. Biodegradable plastics
   II. Retorting
   III. Controlled atmosphere packaging
   IV. Aseptic packaging
   (12)
3 Write detailed notes on:
   I. Fabrication techniques for glasses
   II. Machining of Ceramics
   (12)

OR

3'(a) What are different types of refractories? (03)
3'(b) What are cerments? What properties or combination of properties do they offer? (03)
3'(c) Why most ceramic products are designed to be single piece structures rather than multi part assemblies? (03)
3'(d) Explain chemical, physical and mechanical properties of ceramics. (03)
4. Explain in detail composition, properties and applications of the following:
   I) Ultrahigh molecular weight polythene,
   II) Liquid crystal polymer, and
   III) Thermoplastic elastomer. (12)
5(a) Describe the features of an extruder screw and comment on their specific functions. (04)
5(b) An extruder has a barrel diameter of 100 mm. The screw rotates at 100 rpm, has a channel depth of 6 mm, and a flight angle of 17.5°. What is the highest flow rate of polypropylene that can be achieved? (05)
5(c) An injection-molded nylon gear is found to contain small pores. It is recommended that the material be dried before molding it. Explain why drying will solve this problem. (03)
Maximum Marks: 60  
Credits: 04/05  
Duration: Three Hours

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

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>Determine the equivalent mass of the rocker arm assembly with respect to the x coordinate, corresponding to Figure-1.</td>
<td>[06]</td>
</tr>
<tr>
<td>1(b)</td>
<td>Determine the Fourier series expansion for the system undergoing periodic motion shown in Figure-2.</td>
<td>[06]</td>
</tr>
</tbody>
</table>

OR

1' The schematic diagram of a large cannon is shown in Figure-3. When the gun is fired, high pressure gases accelerate the projectile inside the barrel to a very high velocity. The reaction force pushes the gun-barrel in the opposite direction of the projectile. Since it is desirable to bring the gun barrel to rest in the shortest time without oscillation, it is made to translate backward against a critically damped spring-damper system called the recoil mechanism. In a particular case, the gun barrel and the recoil mechanism have a mass of 500 kg with a recoil spring of stiffness 10 KN/m. The gun recoils 0.4 m upon firing. Find :-
   i. The critical damping coefficient of the damper,
   ii. The initial recoil velocity of the gun, and
   iii. The time taken by the gun to return to a position 0.1 m from its initial position.

2(a) Find the steady-state response of the system shown in Figure-4, for the following [06] contd...
2(b) For a single-degree of freedom damped system under the harmonic motion of the base, show that the amplitude or maximum value of the force transmitted to the base $F_T$ is given by

$$\frac{F_T}{kY} = r^2 \left[ \frac{1 + (2\xi r)^2}{(1 - r^2)^2 + (2\xi r)^2} \right]^{1/2}$$

3(a) Explain the following:

(i) Generalised and Principal coordinates and their use

(ii) Vibration absorbers and their function.

3(b) One of the wheels and leaf springs of an automobile, traveling over a rough road, is shown in Figure-5. For simplicity all the wheels can be assumed to be identical. The automobile has a mass of $m_1 = 1000$ kg and the leaf springs have a total stiffness of $K_1 = 400$ kN/m. The wheels and the axles have a mass of $m_2 = 300$ kg and the tyres have a stiffness of $K_2 = 500$ kN/m. If the road surface varies sinusoidally with an amplitude of $Y = 0.1$ m and a period of $l = 6$ m, determine the critical velocities of the automobile.

4 Show that the natural frequencies of the system as shown in Figure-6 with $k_1 = 3k$, $k_2 = k_3 = k$, $m_1 = 4m$, $m_2 = 2m$, $m_3 = m$, are given by $\omega_1 = 0.46 \ (k/m)^{1/2}$, $\omega_2 = (k/m)^{1/2}$, $\omega_3 = 1.34 \ (k/m)^{1/2}$. Further, determine the Eigen vectors of the system.

OR

4' Derive the stiffness influence coefficients of the system shown in Figure-7.
5 Estimate the fundamental frequency of lateral vibration of a shaft carrying three rotors (masses) as shown in Figure-8 with \( m_1 = 20 \text{ kg} \), \( m_2 = 50 \text{ kg} \), \( m_3 = 40 \text{ kg} \), \( l_1 = 1 \text{ m} \), \( l_2 = 3 \text{ m} \), \( l_3 = 4 \text{ m} \) and \( l_4 = 2 \text{ m} \). The shaft is made of steel with solid circular cross-section of diameter 10 cm.

OR

5' (a) Derive an equation for the principal modes of longitudinal vibration of a uniform bar having both of its ends free.

5' (b) A uniform bar of cross-sectional area \( A \), length \( l \) and Young's modulus \( E \) is connected at both the ends by springs, dampers and masses as shown in Figure-9. State the boundary conditions.
B. TECH. (WINTER SEMESTER) EXAMINATION
MECHANICAL ENGINEERING
FRACURE MECHANICS
ME 419

Maximum Marks: 60 Credits: 04 Duration: Three Hours

Q.No. Question M.M.
1(a) Draw and explain various modes of fracture failure. (03)
1(b) Explain Griffith theory for brittle fracture. Show that the minimum value of stress required to advance a crack for a plane stress case is

\[ \sigma = \sqrt{\frac{2E\gamma}{\pi a}} \]

where \( E \) is the elastic modulus of the material, \( a \) is half crack length and \( \gamma \) is the surface energy per unit area of one cracked surface. (05)

1(c) Draw G and R curves for ductile and brittle materials. (04)

2(a) A large steel plate in a machine is subjected to 700 MPa tensile stress had a 2.5 cm diameter hole at the centre that had a pin pressed into it. The interference of the pin resulted in two small cracks emanating from the diameter hole, as shown in Figure 1. During service, the pin was removed and the hole was left open. Estimate the maximum crack length that can be allowed in the plate. The plain strain fracture toughness for the material is 100 MPa\( \sqrt{m} \) and stress intensity correction factor \( f(a/r) \) is assumed to follow

\[ f(\eta) = 3.2 - 7.3\eta + 19\eta^2 - 32\eta^3 + 32\eta^4 - 14\eta^5 + 2.5\eta^6; \]

where \( \eta = a/r \). Perform 3 iterations only. Take initial value of \( \eta = 0 \). (06)
2. (b) Using the Mises criterion, show that the approximate plastic zone around the tip of mode III crack is a circle of radius

\[ r_p = \frac{3}{2\pi} \frac{K_{III}^2}{\sigma_{YS}^2} \]

OR

2.'(a) A large plate has a crack of length 2a and is loaded under a biaxial stress field \( \sigma \) as shown in Figure 2. The stress and displacement fields have been determined using Westergaard's approach.

(i) Write down the various boundary conditions required while choosing the Westergaard function. Based on these boundary conditions, suggest a suitable Westergaard function \( Z_1 \) for the Mode I (opening mode) fracture.

(ii) Starting from the displacement field near the crack for plate in plane strain condition (\( G \) is shear modulus and \( \nu \) is poisson's ratio)

\[ u_y = \frac{1}{2G} \left[ 2(1-\nu) \text{Im}(Z_1) - \nu \text{Re}(Z_1) \right] \]

Derive the expression for the crack opening displacement (COD) and obtain its maximum value.

(iii) Derive a relationship between fracture parameters CTOD, \( K_1 \) and \( G_1 \) for a crack having small scale yielding near its tip for plane strain case.

2.'(b) Calculate \( K_{eff} \) using Irwin approach for a through-the-thickness crack in a plate of...
width $2W$. Assume plane stress condition and the following stress-intensity relationship:

$$K_{eff} = \sigma \sqrt{\pi a_{eff}} \left[ \sec \left( \frac{\pi a_{eff}}{2W} \right) \right]^{1/2}$$

Take $\sigma = 250$ MPa; $\sigma_{YS} = 350$ MPa; $2W = 203$ mm; $2a = 50.8$ mm.

3. (a) Derive the expression for the energy release rate for a double cantilever beam specimen under displacement control conditions.

3. (b) A material exhibits the following crack growth resistance behavior:

$$R = 6.95(a - a_0)^{0.5}$$

where $a_0$ is the initial half crack length measured in millimeters and $R$ has units of kJ/m$^2$. The elastic modulus of this material is 210 GPa. Consider a wide plate $(a << W)$ with a through thickness crack that is made from this material. If this plate fractures at 140 MPa, compute the following:

(a) The half crack size at failure $(a_c)$.

(b) The amount of stable crack growth (at each crack tip) that precedes failure $(a_c - a_0)$.

OR

3.(b') Determine the energy release rate, using elementary beam analysis for the following configurations:

4(a). What are the various standard test specimens used to determine the critical stress intensity factor $(K_{ic})$. Discuss the constraints on the specimen dimensions to perform a
valid $K_{ic}$ test.

4. (b) A double cantilever beam (DCB) specimen of thickness ($2h=30$ mm) made of a laminated composite material is pulled in a tensile test machine under displacement control condition to determine the inter-laminar critical energy release rate $G_{ic}$. The displacements of the cantilever under different loading for several crack lengths have been given in the Table 1. Complete the table and determine the critical energy release rate.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>$a$ (mm)</th>
<th>$P_c$ (N)</th>
<th>$u$ (mm)</th>
<th>$C$ (mm/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>94.3</td>
<td>2.5</td>
<td>---</td>
</tr>
<tr>
<td>2</td>
<td>42</td>
<td>78.8</td>
<td>5.3</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>64</td>
<td>7.9</td>
<td>---</td>
</tr>
<tr>
<td>4</td>
<td>58</td>
<td>53.5</td>
<td>10</td>
<td>---</td>
</tr>
<tr>
<td>5</td>
<td>67</td>
<td>44</td>
<td>12.8</td>
<td>---</td>
</tr>
</tbody>
</table>

OR

4.(b') Explain the experimental procedure to determine inter-laminar critical energy release rate for II mode fracture.

5. (a) Explain principle of superposition for stress intensity factors.

5. (b) A riveted plate (30 cm wide and 3 cm thick) in a large structure has developed a crack as shown in Figure 3. It will be analysed as a simple case in which the sheet is in uniaxial tension and the rivets above and below the crack are influential in keeping the crack closed. The applied tensile stress and total load by the rivets are $\sigma$ and $P$. If the plate is fabricated from maraging steel with a plane strain fracture toughness of 110 MPa $\sqrt{m}$, what is the maximum stress at failure?
An edge crack of length 3 mm is detected on a large plate supporting a heavy vibrating machine. The machine exerting a constant amplitude cyclic load with $\sigma_{\text{max}} = 310 \text{ MPa}$ and $\sigma_{\text{min}} = 172 \text{ MPa}$. If the plate is made of ferrite-pearlite steel with $K_{\text{ic}} = 165 \text{ MPa} \sqrt{m}$ and follow Paris Law $\frac{da}{dN} = 6.8 \times 10^{-12} (\Delta K)^3$, determine

(a) Propagation life upto failure.

(b) Propagation life if the crack length is not allowed to exceed 25 mm.
1(a) 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, A/F ratio on mass and mole basis.

1(b) A rigid tank contains a mixture of 1 kmol of H₂ and 0.5 kmol of O₂ at 1 atm, 25°C. After ignition, the final pressure and temperature are 5 atm and 2800 K, with combustion products consisting of H₂O, O₂ and H₂. The equilibrium relation among the products can be expressed as: H₂O ↔ H₂ + 1/2O₂. Calculate equilibrium constant K_p and express it in the form of number of moles and pressure P. (Take Gibb's function of formation $\overline{G}_f$ (kJ/kmol) for H₂, O₂ and H₂O as 0, 0, -89031 respectively.)

2 Differentiate between explosion, deflagration and detonation. Derive the Rankine-Hugoniot equation given as:

\[ q = (\gamma / \gamma - 1)(p_2 / \rho_2 - p_1 / \rho_1) - 1/2(p_2 - p_1)(1/\rho_1 + 1/\rho_2) \]; symbols have their usual meaning.

3 Show that the ratio of forward to reverse rate coefficient is equal to the equilibrium constant in terms of concentration. Following rate coefficient for the reaction NO + O → N + O₂ has been suggested: $K_f = 3.8 \times 10^9 \times T \times \exp \left(-20820/T\right)$ in cm³/gmol.s. Determine the rate coefficient for the reverse reaction at 2300K.
4(a) Explain (i) elementary and global reactions (ii) order and molecularity of reaction with the help of suitable examples.

4(b) Discuss chain initiating, chain propagating, chain branching and chain termination reactions with help of examples.

**SECTION 'B'**

5(a) Draw and explain the species variation for a diffusion flame at a fixed height above the fuel jet tube. What is Burke-Schumann theory of diffusion flames.

5(b) Calculate the nitric oxide emission index for a combustor burning ethane ($C_2H_6$) with air, given the following mole fraction measurements in the exhaust duct:

\[ \chi_{CO_2} = 0.110, \chi_{O_2} = 0.005, \chi_{H_2O} = 0.160 \text{ and } \chi_{NO} = 185 \times 10^{-6} \]

Assume that CO and unburned hydrocarbon concentrations are negligible.

6(a) Explain in brief the following terms in reference with the emissions from non premixed combustion: (i) oxides of sulphur, (ii) greenhouse gases, (iii) oxides of nitrogen and particulate matter.

6(b) Draw and explain the variation of temperature and species concentration profiles for a spherically symmetric droplet in case of pure vaporization and for vaporization followed by combustion.

7 A spherically symmetric, 50 $\mu m$ n-octane droplet burns in air at 0.1 MPa and 300 $K$. Calculate the relevant temperature dependent properties and estimate the transfer number $B_T$, burning constant $k_b$, mass burning rate, life time and flame stand off ratio for (i) steady state combustion and (ii) burning with droplet heating.
2014-15

B.TECH. (WINTER SEMESTER) EXAMINATION
MECHANICAL ENGINEERING
REFRIGERATION AND CRYOGENIC ENGINEERING
ME429

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 M.M.
1(a) Derive an expression for COP of Bell-Coleman cycle when the process is carried [06]
out polytropically.
1(b) A vapour compression plant uses R-134a as refrigerant. The evaporator temperature [06]
is -10°C, the condenser pressure is 7.675 bar and there is no sub cooling of the
condensate. The flash chamber pressure is 4.139 bar and the dry saturated vapour
bled off from the flash chamber is mixed with refrigerant from the LP compressor
before entering the HP compressor. The liquid from the flash chamber is throttled
before entering the evaporator. Assuming isentropic compression, determine (a) the
COP of the plant, (b) the mass flow rate of the refrigerant in the evaporator when
the power input to the compressor is 100 kW.

OR

1'(a) Discuss and plot simple vapour compression cycle on pressure enthalpy chart and [06]
discuss the following conditions:
(a) Effect of suction pressure.
(b) Effect of delivery pressure.
(c) Effect of superheating.
1'(b) Discuss with neat sketch and derive expressions for COP of the system for
compound compression with multiple expansion valves and flash intercooling
system.
2(a) Discuss the engineering applications of cryogenics? [06]
2(b) With the help of T-s diagram, Discuss Linde-Hampson process for liquefaction of
Nitrogen.
3(a) List various types of compressors used in refrigeration units? Discuss the
advantages of hermetically sealed compressors.
3(b) Explain the working of thermostatic expansion valve with the help of neat sketch.
4(a) Explain the working of Practical Aqua Ammonia Vapour Absorption Refrigeration
System. How do we ensure pure ammonia at the entry to the condenser? Discuss the
significance and working of aqua heat exchanger.
4(b) Two aqua ammonia mixture streams at saturated liquid state and pressure of 20 bar
each are mixed adiabatically. Stream A has a mass flow rate of 9 kg/s and a
concentration of 0.8, whereas stream B has a mass flow rate of 9 kg/s and a
concentration of 0.2. Determine the temperature, concentration and specific
enthalpy of mixture stream after adiabatic mixing. Also find the concentration of
ammonia in liquid and vapour phases after adiabatic mixing.

OR

4'(a) Explain the method of obtaining an isotherm (in two phase region) of enthalpy-
concentration (h-c) diagram for a mixture. [06]
4'(b) How do we get temperature concentration (T-c) diagram for a mixture (binary)?
[06]
5(a) Define primary refrigerant and discuss desirable properties of primary refrigerants.
Give the refrigerant number for the following: CFC(IP), C_{2}H_{6}, CO_{2}, C_{2}H_{2}F-CF_{3}.
[06]
5(b) What is Food Preservation? Discuss some common methods used for food
preservation. [06]
B.TECH. (WINTER SEMESTER) EXAMINATION
MECHANICAL ENGINEERING
REFRIGERATION AND AIR CONDITIONING
ME429N

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 M.M.
1(a) Explain Cascade refrigeration system and also give its advantages. [06]
1(b) A two stage vapour compression refrigeration system with a direct contact heat exchange (flash chamber) operates with ammonia as the refrigerant. The condenser and evaporator temperatures are 40°C and -30°C respectively. If the capacity of the plant is 30 Tons of refrigeration, estimate the total work of compression and the COP. Had the compression been done in a single stage, what would have been the percentage increase in the work of compression? What is the percentage increase in the COP owing to the staging of the compression process?

OR

1*(a) Derive an expression for COP of Carnot refrigeration cycle. How the value of COP of a Carnot refrigeration cycle varies with higher and lower temperatures? A scientist claims to have developed a Carnot refrigerator, which maintains a freezer temperature of -15°C in a room whose temperature is 35°C and have a COP of 6.5. Justify, whether his claim is true or false.
1*(b) With the help of neat sketch explain the working of “Reduced ambient air craft refrigeration system”.[06]

2(a) Explain the working of Practical Aqua Ammonia Vapour Absorption Refrigeration System. How do we ensure pure ammonia at the entry to the condenser? Discuss the significance and working of aqua heat exchanger.
2(b) Two aqua ammonia mixture streams at saturated liquid state and pressure of 20 bar each are mixed adiabatically. Stream A has a mass flow rate of 9 kg/s and a concentration of 0.8, whereas stream B has a mass flow rate of 9 kg/s and a concentration of 0.2. Determine the temperature, concentration and specific enthalpy of mixture stream after adiabatic mixing. Also find the concentration of ammonia in liquid and vapour phases after adiabatic mixing.

OR

2*(a) Explain the method of obtaining an isotherm (in two phase region) of enthalpy-
concentration (h-c) diagram for a mixture.

2'(b) How do we get temperature concentration (T-c) diagram for a mixture (binary)?

3(a) Describe working of Ice Plant. What would be the nature of ice if it is formed quickly?

3(b) What is Food Preservation? Discuss some common methods used for food preservation.

4(a) Discuss the various factors affecting human comfort. What is comfort chart?

4(b) An air-conditioned space is maintained at 27°C DBT and 50% RH. The ambient conditions are 40°C DBT and 27°C WBT. The space has a sensible heat gain of 14 kW. Air is supplied to the space at 7°C saturated. Calculate: (i) Mass of moist air supplied to the space in kg/h. (ii) Latent heat gain of space in kW. (iii) Cooling load of the air washer in kW if 30% of the air supplied to the space is fresh, the remainder being recirculated.

5(a) Explain frictional losses and dynamic losses in flow through duct. Give an expression for frictional pressure drop in ducts.

5(b) Explain static regain method for the sizing of the air-ducts. Write its advantages and disadvantages also.
# 2014-15

**B.TECH. AUTUMN (VII SEMESTER) EXAMINATION**
**MECHNICAL ENGINEERING**
**FLUID MACHINERY**
**ME-433**

Maximum Marks: 60  
Credits: 04  
Duration: Three Hours

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**Question**

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>Show with the help of diagram that effective head “H” of a centrifugal pump may be expressed as ( H = H_s + H_d + H_f + H_f - \frac{v_d^2}{2g} ). All terms have usual meanings.</td>
<td>[04]</td>
</tr>
<tr>
<td>1(b)</td>
<td>A centrifugal pump impeller is 25 cm in diameter and the passage width at outlet is 2 cm. The blade angle at outlet is 45°, running at 1000 rpm. The discharge is 45 l/s. Calculate the fraction of kinetic energy of discharge which is subsequently recovered in the casing. Neglect hydraulic friction and other losses. The pump is delivering against a head of 10 m.</td>
<td>[08]</td>
</tr>
<tr>
<td>2(a)</td>
<td>Explain the phenomenon of surging, choking and stalling.</td>
<td>[04]</td>
</tr>
<tr>
<td>2(b)</td>
<td>A turbo compressor consumes 220 KW when pumping 1Kg/s of air from 1 Kg/cm² abs to 5 Kg/cm² abs. In the inlet duct, the air has temp. of 25°C and in the exit duct the velocity is 150 m/s. Calculate (i) Static and total temp. in exit duct. (ii) Change of entropy. (iii) Isentropic efficiency based on static values. Assume negligible velocity at inlet and also negligible mech. losses.</td>
<td>[08]</td>
</tr>
<tr>
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<td><strong>OR</strong></td>
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</tr>
<tr>
<td>2(b)</td>
<td>Derive an expression for degree of reaction for an axial flow compressor and show that for reaction equal to 0.5, stationary and moving vanes are symmetrical.</td>
<td>[08]</td>
</tr>
<tr>
<td>3(a)</td>
<td>With a neat sketch explain the working principle of hydraulic coupling</td>
<td>[06]</td>
</tr>
</tbody>
</table>

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contd... 2
3(b) Calculate the work saved in overcoming friction by fitting large air vessel used near the suction and delivery side of reciprocating pump of the following specification. Pump is single acting, Speed=60 rpm, stroke=35 cm, dia. Of cylinder= 20 cm, dia. of delivery pipe is10 cm and 50 cm long and dia. of suction pipe is 15 cm and 8 m long. Take \( \lambda = 4f = 0.04 \).

4 A Francis turbine of dia. 3 m develops 6750 KW at 300 rpm under a net head of 45 m. A geometrically similar model of scale ratio 1:8 is to be tested at a head of 9 m. Estimate the size, speed, discharge and power develop by the model. What is the specific speed of model. Assume over all efficiency of model and prototype is 82%.

OR

4' For a Francis turbine, power = 10,000 KW, head = 200 m, \( \eta = 85\% \), speed = 540 rpm, velocity of flow at inlet= 9 m/s, hyd. Efficiency = 87 \%, ratio of wheel dia. to width at inlet= 10, Area occupied by thickness of blades= 7.5 \% of the area of water way. Find the area, tangential velocity and velocity of whirl at inlet and angle at entry. Discharge is radial.

5(a) Show that the efficiency of Pelton wheel is maximum when the speed of bucket equals half the velocity of the jet.

5(b) A Pelton wheel 2.5 m dia. operates under following conditions; head = 300 m, speed = 300 rpm, coeff. Of velocity of jet = 0.98, blade friction coeff. = 0.95, blade angle = 165\(^\circ\), dia. of jet = 20 cm, mech. Efficiency = 0.95. Determine (i) Power developed, (ii) hyd. efficiency (iii) specific speed.

OR

5(b') A Kaplan turbine runs under a head of 5.3 m and develops 7300 KW, the velocity of flow is 6 m/s and dia. of hub is 0.36 m of the external diameter. The Efficiency of turbine is 87 \% and the peripheral speed of the blade is 20 m/s. Determine (i) speed in rpm (ii) specific speed and (iii) dia. of wheel.
1(a) Discuss the role of ‘Operation Research’ in decision making. Support your answer with the help of practical examples.

1(b) An organization has to schedule ten orders on four machines. The organization is interested in improving upon the present means of scheduling and machine assignment. The orders and the time requirements on the various machines are given in the table below. Use the ‘index approximation method’ to solve the allocation problem.

<table>
<thead>
<tr>
<th>Order No.</th>
<th>Machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
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<td>8</td>
<td>17</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Total Available Time (in hours)</td>
<td>40</td>
</tr>
</tbody>
</table>
2. Answer any two of the followings:

(a) Solve the following linear programming problem using 'simplex method'.
Maximize \[ Z = 4x_1 + 3x_2 + 6x_3 \]
Subject to \[ 3x_1 + x_2 + 3x_3 \leq 30 \]
\[ 2x_1 + 2x_2 + 3x_3 \geq 40 \]
and \[ x_1, x_2, x_3 \geq 0 \]

(b) Consider the below given data matrix for shop loading, where entries are costs of loading four jobs on four machines. Determine the minimum cost schedule, using assignment algorithm.

<table>
<thead>
<tr>
<th></th>
<th>Machine 1</th>
<th>Machine 2</th>
<th>Machine 3</th>
<th>Machine 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Job 1</td>
<td>7</td>
<td>9</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Job 2</td>
<td>10</td>
<td>7</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Job 3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Job 4</td>
<td>12</td>
<td>6</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

(c) Consider the following transportation problem and its initial basic feasible solution. Find the optimal solution, using stepping stone procedure.

<table>
<thead>
<tr>
<th></th>
<th>Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
</tr>
<tr>
<td>Source</td>
<td>$200</td>
</tr>
<tr>
<td>S1</td>
<td>$100</td>
</tr>
<tr>
<td>S3</td>
<td>$300</td>
</tr>
<tr>
<td>Need</td>
<td>200</td>
</tr>
</tbody>
</table>
3(a) Describe, using examples, the applications of game theory in decision making.

3(b) For the following payoff table, use the graphical procedure to determine the value of the game and the optimal mixed strategy for each player according to the minimax criterion.

<table>
<thead>
<tr>
<th>Source</th>
<th>Plant</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
</tr>
<tr>
<td>S1</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>S2</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td>-200</td>
</tr>
<tr>
<td>Need</td>
<td>200</td>
<td>300</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Player 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Player 1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

OR

An investment proposal for income expansion requires an initial disbursement of $190,000. The most likely outcome is for after-tax returns to amount to $90,000 per year for 4 years. There is no salvage value, and the minimum attractive rate of return is 10 percent. A risk analysis of the concerned proposal recognizes that the most likely cash flow has a probability of only 0.5. A
pessimistic appraisal of the future concedes returns might amount to only $45000 per year. Under the most optimistic assessment, returns could total $120000 per year. The probabilities of pessimistic and optimistic returns materializing are 0.3 and 0.2 respectively. The duration of returns is also questionable; probabilities for 2, 3, 4, and 5 years are, respectively, 0.2, 0.2, 0.5, and 0.1. Perform investment analysis using acceptable investment diagram.

4 Answer any two of the followings:

(a) Describe the basic structure of a queuing model. Using birth and death process, derive the relationships for expected number of customers in a queuing system (L) and waiting time in a system (W). Consider a single server case (M/M/1).

(b) A branch of a national bank has only one typist. The typing rate is randomly distributed approximating a Poisson distribution with mean service rate of 8 letters text per hour. The texts arrive at a rate of 5 per hour during the entire 8-hour work day. If the typewriter is valued at Rs. 1.5 per hour, determine:
   (i) Equipment utilization.
   (ii) Average system time.
   (iii) Average cost due to waiting on the part of typewriter.

(c) The tool room company's quality control department is governed by a single clerk who takes an average of 5 minutes in checking parts of each of the machine coming for inspection. The machines arrive once in every 8 minutes on the average. One hour of the machine is valued at Rs. 15 and the clerk's time is valued at Rs. 4 per hour. What is the average hourly queuing system cost associated with the quality control department?

5(a) The data for a short project is given in the table below:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Immediate Predecessors</th>
<th>Expected-Time (in days)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>A</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>E</td>
<td>C, F, G</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>F</td>
<td>D</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>G</td>
<td>B</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>
Construct a PERT diagram. Find the critical path and critical path time.

Assuming independent activities that are normally distributed, what is the probability of completing the project in 19 days or fewer?

Write few lines about reliability. Explain the method used for determining the failure rate and mean life of the product. Use numerical example to support your answer.

The following values of Standard Normal distribution may be used if required.

<table>
<thead>
<tr>
<th>z</th>
<th>0.00</th>
<th>0.01</th>
<th>0.02</th>
<th>0.03</th>
<th>0.04</th>
<th>0.05</th>
<th>0.06</th>
<th>0.07</th>
<th>0.08</th>
<th>0.09</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.1841</td>
<td>0.1814</td>
<td>0.1768</td>
<td>0.1726</td>
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<td>0.1642</td>
<td>0.1602</td>
<td>0.1562</td>
<td>0.1522</td>
<td>0.1481</td>
</tr>
<tr>
<td>-0.8</td>
<td>0.2119</td>
<td>0.2090</td>
<td>0.2061</td>
<td>0.2033</td>
<td>0.2005</td>
<td>0.1977</td>
<td>0.1949</td>
<td>0.1922</td>
<td>0.1894</td>
<td>0.1867</td>
</tr>
<tr>
<td>-0.7</td>
<td>0.2420</td>
<td>0.2389</td>
<td>0.2358</td>
<td>0.2327</td>
<td>0.2296</td>
<td>0.2266</td>
<td>0.2236</td>
<td>0.2206</td>
<td>0.2177</td>
<td>0.2148</td>
</tr>
<tr>
<td>-0.6</td>
<td>0.2743</td>
<td>0.2709</td>
<td>0.2676</td>
<td>0.2643</td>
<td>0.2611</td>
<td>0.2578</td>
<td>0.2546</td>
<td>0.2514</td>
<td>0.2483</td>
<td>0.2451</td>
</tr>
<tr>
<td>-0.5</td>
<td>0.3085</td>
<td>0.3050</td>
<td>0.3015</td>
<td>0.2981</td>
<td>0.2946</td>
<td>0.2912</td>
<td>0.2877</td>
<td>0.2843</td>
<td>0.2810</td>
<td>0.2776</td>
</tr>
</tbody>
</table>
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 M.M.

1 Attempt any TWO parts.
   1(a) What is numerical control (NC) machine tool? Explain NC process in detail. [06]
   1(b) With the help of schematic diagram of an NC machine tool explain the following: i) MCU, ii) DPU and iii) CPU. Draw various possible coordinate frames illustrating right hand coordinate system. [06]
   1(c) What do you mean by ‘Zero point’ with respect to NC control machines? Draw a typical standard NC tape and explain it. [06]

2 Attempt any TWO parts.
   2(a) What are various types of input media in NC machine tools? Illustrate briefly. [06]
   2(b) What are the essential requirements of a feed drive? Differentiate between AC and DC drives. [06]
   2(c) What is the difference between Drives and Actuation Systems in NC machine tools? What actuation mechanisms are provided for positional control? [06]

3 Attempt any TWO parts.
   3(a) What is a CNC system? What are its components? How it is different from NC system? [06]
   3(a) Describe the construction and working of an encoder. [06]
   3(c) What is program format? Describe the following program format in detail.
      i) Fixed sequential format, ii) Tab sequential format and iii) Word address format [06]
4 (a) What are the fixed cycles? Discuss how a fixed cycle can be useful in writing a part program for any two operations of your choice.

4 (b) Write a part programme using G-M codes for the component shown in figure 1. The machining parameters are: Cutting Speed = 1500 rpm; Feed = 250 mm/min and Depth of cut = 1 mm.

4' (a) A profile milling operation is to be performed to generate the outline of the part in figure 2. One hole is also to be drilled in the part. The part is 10 mm thick. Assume all the required machining parameters. Write a part programme using G-M codes for this part.

4' (b) What is cutter radius compensation? Discuss when it is used and how it is included in the...
part programme?

5(a) What is APT? How are geometric and motion statements made in APT?

5(b) Write a program in APT for the machining the part as shown in figure 3. The part is of 10 mm thickness. Assume appropriate tool diameter, spindle and feed rates.
Q.1 (a) A turboprop aircraft engine at Sea-level, ISA standard takeoff condition (take-off speed 70m/s) is designed with a CPR of 11.0, TIT of 1400 K and a mass flow rate of 7.5 kg/s. Assume that 70% of enthalpy drop occurs in the power turbine driving the propeller and rest occurs through the exhaust nozzle. Following component efficiencies can be assumed:

Polytropic efficiencies of Gas generator, power turbines and compressor 0.87
Isentropic efficiency of intake and exhaust nozzle 0.95
Gearbox efficiency 0.95
Propeller efficiency 0.75

Compute the exhaust nozzle thrust, shaft horse power and equivalent power at the take-off speed. (6)

Q.1(b) Answer any two:
(i) Explain briefly what are the desired characteristics (specific thrust, SFC, TIT and CPR) required for engines designed for heavy-haul jets such as Globemaster? (3)
(ii) Why are turboprop aircrafts not used for long-range flights? (3)
(iii) Why are unducted contra-rotating turbofans not used in commercial airliners? (3)
(iv) Why does the SFC of turbojets increases with increase of flight Mach number? (3)

Q.2 (a) A supersonic passenger aircraft is being designed for flight Mach number 2.5 at an altitude where the ambient pressure and temperature are 9 KPa and 220 K, respectively. The engine inlet configuration shown in Figure 1 allows for double oblique shock deceleration followed by a zone of subsonic deceleration. The Mach number is 0.5 at the engine inlet plane i. Losses in the subsonic diffuser are neglected.
Determine
(i) The Mach number \( M_1 \) and \( M_2 \) in the zones 1 and 2.
(ii) the wave angles \( \theta_1 \) and \( \theta_2 \) shown in the figure
(iii) The overall stagnation pressure ratio \( P_{\infty}/P_{\infty} \) (6)
Q.2(b) Explain briefly the sub-critical, critical and supercritical modes for external shock diffusers?

OR

Q.2'(b) What happens to combustion efficiency with altitude and how does it relate to NO\textsubscript{x} formation?

Q.2(c) Why is phenomenon of "buzz" encountered in case of supersonic inlets?

OR

Q.2'(c) What are the problems that arise due to introduction of isentropic external diffusers in supersonic inlets?

Q.3.(a) Consider a chemical rocket engine in which the combustion chamber pressure and temperature are 30 atm and 3500 K, respectively. The area of the nozzle exit is 16 m\textsuperscript{2} and is designed so that the exit pressure equals ambient pressure at a standard altitude of 25 km. For the gas mixture, assume γ = 1.12 and the molecular weight is 20. At a standard altitude of 25 km, calculate (a) specific impulse, (b) exit velocity, (c) mass flow, and (d) thrust. The ambient pressure at 25 km altitude is \( P_a = 0.025 \) atm.

Q.3(b) Consider a two-stage rocket with the following design characteristics. First stage: Propellant mass = 8000 kg; structural mass = 1000 kg. Second stage: Propellant mass = 4000 kg; structural mass = 300 kg. The payload mass is 150 kg. The specific impulse for both stages is 300 sec. Calculate \( \dot{m}_i, \dot{e}_i, \dot{R}_i \) for each stage and the final burnout velocity.

Q.4(a) How do Hall thrusters overcome the problem of charge density at engine exit which plagues ion thrusters?

Q.4(b) Mention the different electric thrusters and their specific impulses that are appropriate for small, medium and large spacecrafts?

Q.4(c) What type of engines will be required for interstellar travel in future and why?

Q.4(d) Why do magnetoplasmadynamic (MPD) thrusters require large current for generation of thrust?

Q.5 We wish to perform off-design performance analysis of single-spool turbojet engine for which design parameters are known to us at Ma=0.6 and altitude of 8 km. The flight Mach number of the aircraft at off-design conditions is 0.85 while the altitude is held constant. Mention the overall iteration procedure that we need to follow in order to compute the off-design thrust. While going through the procedure, follow these steps...
Q.5 We aim to perform off-design performance analysis of a turboprop engine (basically a gas-generator with a free power turbine driving a propeller) for which design parameters are known. The altitude of the aircraft has changed and we wish to compute the off-design shaft power. For this we need to follow the overall iteration procedure, and go through the following steps:

(i) Draw a schematic of the engine with proper station numbering
(ii) Express mathematically the flow and work compatibility relationships between various components
(iii) Write an expression for the off-design shaft power mentioning how various thermodynamic variables in the expression are evaluated
(iv) Draw a flow chart of the overall iteration procedure

Figure 1: Mixed compression diffuser