II Semester M.Tech. Examination (2015-16)
Mechanical Engineering
(Industrial & Production Engineering)

Quality Management (ME-622)

Maximum marks: 60  
Credits: 04  
Time allowed: 3 hours

Note: 1. Answer all questions, preferably in the sequence given.
2. Statistical tables may be used with the permission of the invigilator.
3. Assume suitable data if missing. Notations used have their usual meaning.

Q1. (a) Define quality and its various dimensions.  
(b) State any four points of Deming’s philosophy of quality.  
(c) Differentiate with example between assignable and chance causes of variations in quality.

Q2. (a) The $\bar{x}$ and R charts for a process show that the process is in control, still some pattern in the variability can be seen on the charts. Discuss any two such patterns and their likely causes.

(b) Consider a manufacturing process producing a product P. The following data are collected for the purpose of constructing control charts. This has also been observed that the quality characteristic under study is normally distributed and the two charts ($\bar{x}$ and $s$) indicate that the process is stable.

$\bar{x} = 20; \bar{s} = 1.5; n=50; n=6$; Specifications for the quality characteristic $= 19 \pm 4.0$.

(i) What are your conclusions regarding the ability of the process?
(ii) It is given that if an item exceeds the upper specification limit it can be reworked, while if it is below the lower specification limit it must be scrapped. What per cent of the scrap and rework is the process now producing?
(iii) If the process is centred at the nominal specification, what would be the effect on the per cent scrap and rework?

OR

Q2'. (a) Briefly explain the construction of a control chart for attributes.

(b) Consider a manufacturing process producing a product P. The following data are collected for the purpose of constructing control charts. This has also been observed that the quality characteristic under study is normally distributed and the two charts ($\bar{x}$ and $R$) indicate that the process is stable.

$\bar{x} = 360; \bar{R} = 8.91; n=9$; Specifications for the quality characteristic $= 358 \pm 6$.

Contd.....2.
(i) Compute the control limits for the $\bar{x}$ and R charts.
(ii) Suppose the mean shifts to 357, what is the probability that the shift will be detected on the first sample following the shift?
(iii) Calculate the percentage non-conforming.

Q3. (a) Define gauge reproducibility and P/T ratio. (4)

(b) Ten parts are measured three times by the same operator in a gauge capability study. The data obtained are given in Table-1. Estimate total variability and product variability. What percentage of total variability is due to gauge? If specifications on the part are at 100 ± 15, find the P/T ratio for this gauge. (8)

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(Table-1)

Q4. An acceptance sampling plan has the sample size 100 and acceptance number 3. Draw an OC curve for this plan with fraction nonconforming as .01, .02, ....... 0.10. Show the effect on the OC curve of changing the sample size to 50. Also find how does the revised plan affect the sampling risks if the AQL=0.02 and LTPD=0.08. (12)

OR

Q4'. Suppose you are the auditor for a bank operation. You have decided to consider error rates acceptable when there is one or less in 100 operations. You want to clear the bank's operation (accept their procedures) with 95 percent confidence when the error rate is this low. On the other hand, if the error rate climbs to five or more per 100 operations, you want to reject the bank's operation with 90 percent probability. How many operations of the bank should be audited and why? How many operations can you find the bank in error and still pass it on the audit? (12)

Contd....3.
Q5. (a) Define reliability, failure rate, mean-time-to failure, mean-time-between failure, availability, and maintainability of systems.

(b) For the system shown in Figure-1, determine the system reliability for 2000 hr operation and find the mean time to failure. Assume that all three components have an identical time-to-failure distribution that is exponential, with a constant rate of failure of 0.0005/hr. What is the mean time to failure of each component? If it is desired for the system to have a mean time to failure of 4000 hr, what should the mean time to failure be for each component?
1. Discuss the effect of following process parameters on MRR in AJM process:
   (a) SOD or NTD (b) abrasive grain size and flow rate (c) nozzle Pressure (d) mixing Ratio.

2. Derive equation to find the tool profile for the following work shape: $Y = 10 + 0.3X - 0.05X^2$ (X and Y are in cm). Given that: Applied Voltage = 15V, over potential = 0.67V, feed velocity 0.75 mm/min, Work Material: Copper (atomic weight = 63.5, Z = 1, density = 8.96 g/cm³, $k = 0.2 / \mu$-ohm-cm).

OR

The equilibrium gap when machining (electrochemically) iron, using NaCl solution in water as the electrolyte, is found to be 0.2 mm with an operating voltage of 12 V. Iron dissolves at valency 2, the density of iron is 7.8 g/cm³, and the specific resistance of the electrolyte is 2.8 ohm-cm. Calculate the metal removal rate/unit work surface area. The overvoltage may be taken as 1.5 V.

3. (a) Differentiate between chemical machining and electrochemical machining. Enlist the application of both manufacturing processes.

3. (b) Discuss the various components of Abrasive Water Jet Machine and process capabilities.

OR

For spark machining of a 5 mm X 5 mm square through hole in solid low carbon steel plate of 5 mm thickness, a brass tool is used with kerosene as the dielectric. The resistance and the capacitance in the relaxation circuit of the spark generator are 100Ω and 15 μF, respectively. The supply DC voltage is 220 V and the gap is maintained at such a value that the discharge takes place at 120 V. Estimate the time required to complete the job.

Contd.....2.
4(a) Explain the electrochemistry of Electrochemical Machining Process.

4(b) What is sporadic break down of Anodic film in ECM process? Explain in detail.

5(a) Discuss the EDM process in detail with neat diagram. What are the process capabilities of this process?

5(a') The composition of a Nimonic alloy turbine blade is 18% cobalt, 62% Ni, and 20% chromium. It is being machined electrochemically with a current of 1500 amp. Find out the volume removal rate. The dissolution valency of chromium is 6, whereas that for both nickel and cobalt is 2.

OR

A 10 mm diameter hole has to be drilled in a 5 mm HSS sheet by EDM using a relaxation circuit. The required surface finish is 20 μ. Determine the capacitance to be used when the supply and discharge voltages are 220 V and 150 V, respectively, the resistance being 50 Ω. Also, estimate the time required to complete the job.
II Semester M.Tech. Examination (2015-16)
Mechanical Engineering
(Industrial & Production Engineering)

Quality, Reliability & Maintenance (ME-627)

Maximum marks: 60  
Credits: 04  
Time allowed: 3 hours

Note: 1. Answer all questions, preferably in the sequence given.
2. Statistical tables may be used with the permission of the invigilator.
3. Assume suitable data if missing. Notations used have their usual meaning.

Q1. (a) Explain how productivity and quality are related.  (4)

(b) State any four points of Deming’s philosophy of quality.  (4)

(c) Explain the various components of the cost of quality failure.  (4)

Q2. (a) The $\bar{x}$ and R charts for a process show that the process is in control, still some pattern in the variability can be seen on the charts. Discuss any two such patterns and their likely causes.  (4)

(b) Consider a manufacturing process producing a product P. The following data are collected for the purpose of constructing control charts. This has also been observed that the quality characteristic under study is normally distributed and the two charts ($\bar{x}$ and R) indicate that the process is stable.

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OR

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Contd.....2.
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OR

Q4'. A purchasing manager decided to take a sample of machine parts received from a certain supplier for acceptance sampling. She would agree to a 10 per cent error of accepting the parts if the incoming lot quality were 8 defects out of 100 or worse. She would also take a 5 per cent error of rejecting a good incoming lot with 2 defects out of 100 or less. Determine the alternative single sampling plans considering the viewpoints of both - the producer as well as consumer. Which plan would you recommend and why if the criterion is to minimize the inspection cost?

Contd.....3.
Q5. (a) Explain with the help of a diagram the various phases of a typical life-cycle curve of an equipment.

(b) Explain with the help of suitable graphs how to decide between preventive and breakdown maintenance.

(c) The manufacturer of a grinder tested its products to assess the various maintenance performance measures. Fifty grinders were each tested for a running time of 1000 hours. It was found that there were a total of 60 failures during the testing phase. In total, 1350 hours were lost on account of identifying the problem and restoring it back to working condition. Based on this information, compute the failure rate of grinders and their availability.
1. Explain moving coordinate system. A moving particle \( P \) (as shown in figure 1) in moving coordinate system \( \text{oxyz} \) has position vector \( r \). This coordinate system is also moving with respect to the global stationary coordinate system \( OXYZ \). \( \mathbf{I}, \mathbf{J}, \mathbf{K} \), and \( \mathbf{i}, \mathbf{j}, \mathbf{k} \) are unit vectors along \( X, Y, Z \) and \( x, y, z \) directions and \( R_0 \) is the position vector of the origin of the \( \text{oxyz} \) coordinate system with respect to \( OXYZ \) coordinate system. Derive the expression for absolute velocity and absolute acceleration of the particle \( P \) with respect to \( OXYZ \).

\[ \text{Figure 1} \]

\[ \text{Figure 2} \]
Figure 2 shows a block $P$ that slides on a slender rod $i$. The rod is connected to the ground by a pin joint at $O$ and rotates with angular velocity $\dot{\theta}_i$. Determine the absolute velocity and acceleration of point $P$ using the above relations.

**2. (a)** Determine the degrees of freedom of the mechanisms shown in figure 3.

![Figure 3](image)

2. (b) Consider the double-slider two-loop linkage shown in figure 4, using vector approach, derive displacement equations. For $r_1=1$, $r_2=5.2$, $r_3=5$, $r_{de}=4$, $r_{cd}=1.5$, $\theta_1=\pi/3$, find $\theta_2$, $\theta_3$, $r_0$ and $r_\infty$. 

Contel - 3.
3. Using vector approach, find the link orientation and velocities of the RSSC spatial linkage shown in figure 5 for $\gamma=30^\circ$, $\theta=45^\circ$, and crank angular velocity $\omega_1=50$ rad/sec counter-clockwise. Take $r_0=200$mm, $r_1=100$mm, $r_2=300$mm.

![Figure 4](image)

**Figure 4**

![Figure 5](image)

**Figure 5**

4. The derive link of an RSSR linkage rotates at a constant speed (figure 6). The planes of rotation of the derive crank and the driven crank are perpendicular, and the fixed bearing of the crank is in the plane of the driver. Write a set of scalar equations required to find...
the acceleration of the driven crank.

5. Explain Freudenstine's method for the three position synthesis of four bar mechanism. Synthesize a four bar mechanism to generate \( y = \sin x \) for \( 0 \leq x \leq \pi/2 \) with three Chebyshev's accuracy points. Take suitable rotations of the driver and driven links.

6. Develop set of linear equations for synthesizing RSSR mechanism as a function generator with six accuracy points. Identify design variables and outline the procedure for solving them.

7. Synthesize 4R spherical mechanism to generate \( y = x^2 \) for \(-1 \leq x \leq 1\) with proper choices of parameters. Obtain the solutions with three accuracy and five accuracy points.
Q.No. | Question | M.M.
--- | --- | ---
1 | Discuss in brief the steps involved in the finite element analysis of any physical system. Let the differential equation governing the deflection of Euler Bernoulli's beam of length $L$, simply supported at both the ends is given by \[ EI \frac{d^4v}{dx^4} + Q = 0 \]
   Derive the approximate solution for the deflection ($v$) using weighted residual method. | [12]
2 (a) | Derive the element level governing equation for a three noded bar element. Assume the bar to be of uniform cross sectional area $A$, Youngs Modulus $E$ and of length $L$. The bar is subjected to an axial distributed load of intensity $q$ N per unit length. | [08]
2 | What are shape functions? Derive the shape functions for a two noded Euler Bernoulli beam element. | [04]
   OR
2' | For the truss structure shown in Fig. 1, find
   (i) Transformed stiffness matrix of each element.
   (ii) Assembled system of equations
   (iii) Displacement components of point B in $x$ and $y$ direction. | [12]
3 | Write down the assumption involved in Euler Bernoulli beam theory and explain how it is different from Timoshenko beam theory. Further derive the element level | [12]
   Contd.....2.
governing equation for Timoshenko beam element and compute the stiffness matrix, and load vector for a beam carrying uniformly distributed transverse load $w$ N per unit length.

4 (a) Explain in brief

i) isoparametric, subparametric and super parametric formulations with their application

ii) Langrangian and serendipity elements

4 (b) Explain in brief the Plane stress and plane-strain conditions. Further, derive the expressions for their constitutive matrix for linear elastic isotropic material.

5 (a) Derive the element level governing equation for a four-noded isoparametric element.

(b) Explain in brief the Gauss Quadrature numerical integration procedure. Further, explain the process of selecting the integration points and the associated weight functions for 4-noded and 8-noded isoparametric plane stress/strain element.

**OR**

5' Derive the constitutive matrix for 3D elasticity problem for linear elastic isotropic material. Further obtain the element level governing equation for 3D 8-noded isoparametric element.

![Fig. 1](image-url)
Q.1 (a) Consider a semi-infinite incompressible Newtonian liquid of viscosity $\mu$ and density $\rho$ bounded below by a plate at $y=0$. Consider both the fluid and plate initially at rest. Suddenly a constant velocity $V$ is applied to the plate.

(i) Specify the governing equation and the boundary and initial conditions.
(ii) Assuming a similarity solution of the form $u(y,t) = V f(\zeta)$ where $\zeta = \frac{y}{2\sqrt{\nu}}$, show that the resulting equation is given by $f'' + 2\zeta f' = 0$, if $a = \frac{1}{2\sqrt{\nu}}$.
(iii) Finally show that solution of above equation is $u = V[1 - erf(\frac{y}{2\sqrt{\nu}})]$.

(b) Show that that pressure-driven steady flow in a long tube of triangular cross-section of side $a$ has velocity profile given by $U(y, z) = -\frac{1}{36\mu a^2}(2\sqrt{3}z+a)(\sqrt{3}z+3y-a)\sqrt{3z-3y-a}$, if the sides of the triangle lie on the lines $2\sqrt{3}z+a = 0$, $\sqrt{3}z+3y-a = 0$ and $\sqrt{3}z-3y-a = 0$.

OR

1'(a) Consider fully-developed flow of a Newtonian fluid between two coaxial cylinders of radii $R$ and $\kappa R$, where $\kappa < 1$. The outer cylinder is translated with velocity $V$, while the inner is held fixed. Write the relations for the axial velocity $u$ for the two cases (a) $\kappa - > 0$ and (b) $\kappa - > 1$. Start from the axial component of cylindrical Navier-Stokes equation

\[ \rho \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial r} + u \frac{\partial u}{\partial \theta} + u \frac{\partial u}{\partial z} \right) = -\frac{\partial p}{\partial z} + \mu \left[ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial u}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 u}{\partial \theta^2} + \frac{\partial^2 u}{\partial z^2} \right] + \rho g_z \]

and make relevant assumptions. Here $u$ is the axial component of velocity.
(b) Consider two immiscible incompressible liquids A and B of densities \( \rho_A \) and \( \rho_B \)
and viscosities \( \mu_A \) and \( \mu_B \) flowing between two plates. The fluid A has depth \( H_A \) while
fluid B which is lighter flows on top with depth \( H_B \). The upper plate is given velocity \( V \) while the lower is held fixed. Starting from the Navier-Stokes equation in Cartesian
coordinates and with relevant boundary conditions, show that the velocity profiles are
given by \( u_A = \frac{\mu_A V}{\mu_A H_A + \mu_B H_B} y, 0 \leq y \leq H_A \) and \( u_B = V - \frac{\mu_A V}{\mu_A H_B + \mu_B H_A} (H_A + H_B - y), H_A \leq y \leq H_A + H_B \).

(9)

Q.2(a). Consider the flow of a uniform stream of speed \( Q_\infty \) at angle of attack \( \alpha \)
past a thin airfoil whose camberline is given by

\[
\eta_c = h(1 - \frac{x}{c})(1 - \frac{\lambda x}{c})x
\]

where \( h << 1 \) and \( \lambda \) is a constant. Show that \( C_l = 2\pi(\alpha + \epsilon) \), \( C_m = 2(\mu - \frac{\pi}{4} \alpha - \frac{\epsilon}{4}) \) where
\( \epsilon = \frac{h}{8(4 - 3\lambda)} \) and \( \mu = \frac{(\pi / 64)}{h\lambda} \). Use \( C_l = 2\pi(A_0 + \frac{A_1}{2}) \) and \( C_m = -\frac{\pi}{2}[A_0 + A_1 - \frac{A_2}{2}] \)
where \( A_0 = \alpha - \frac{1}{2} \int_0^\pi \frac{d\phi}{dx} d\phi \) and \( A_n = \frac{2}{\pi} \int_0^\pi \frac{d\phi}{dx} \cos n\phi d\phi \), \( n=1,2,3,.. \).

(8)

(b) Consider the flow of uniform stream of speed \( Q_\infty \) at angle of attack \( \alpha \) past a
biplane consisting of two flat plate airfoils of chord \( c \) located at a distance \( h \) apart.
Find the lift coefficient of each airfoil using lumped vortex element theory.

(7)

Q.3. (a) Explain very briefly why does a baroclinic flow result in generation of
vorticity and circulation.

(3)

(b) What happens to anisotropic turbulence as it passes through the converging zone
of the subsonic wind tunnels?

(3)

(c) What differentiates two-dimensional turbulence from the usual three-dimensional
turbulence?

(3)

(d) Explain briefly the coherent structures found in near-wall turbulent flows.

(3)

(e) What do we measure by computing two-point spatial velocity correlations in
turbulent flows?

(3)

OR

Q.3'(a) In the turbulent energy equation given below

\[
\frac{d}{dt} \left( \frac{1}{2} u_i^2 \right) = -\frac{\partial}{\partial x_j} \left( \frac{1}{\rho_0} \mu_{ij} + \frac{1}{2} u_i^2 u_j - 2\nu \overline{u_i u_j} \right) - \overline{u_i u_j U_{i,j}} + g\overline{wT'} - 2\nu \overline{\epsilon_s \epsilon_s}
\]

Explain briefly the physical significance of the first three terms in the brackets followed
by significance of the last three terms.

(7)

(b) Briefly highlight the terms intermittency, entrainment and momentum flux in turbulent jets.

(4)

(c) Why flux Richardson number \( R_f = \frac{g\overline{wT'}}{\nu \overline{(dT'/dz)}} \) should be less than 0.25 for turbulence to be self-sustaining in stratified flows?

(4)

Contd.....3.
Q.4 (a) Starting from the basic geostrophic flow equations, show that the horizontal velocities are along the lines of constant pressure i.e. isobars act as streamlines of the flow.

(b) Why do horizontal temperature gradients result in generation of thermal wind i.e. geostrophic velocities having vertical shear?

(c) Rotating inviscid flows away from boundaries exhibit a phenomenon that velocities do not vary in the vertical direction i.e. \( \frac{\partial u}{\partial z} = 0 \). What significance does it have for the atmospheric flows?

(d) On what factors do the thickness of Ekman layers that form on ocean surfaces depend upon? Why do they form spiral motion below the ocean surface?
Answer any four questions. Assume suitable data if missing. Notations used have their usual meaning.

Q.No. | Question | M.M.
--- | --- | ---
1 | Derive the generalised viscous energy equation for laminar boundary layer during forced Convection and hence, obtain the 2-D energy equation for axi-symmetric flow in a circular tube. | [15]
2 | With suitable assumptions and neat diagram, obtain Integral Energy Equation for the steady axial fluid flow over a body of revolution whose temperature and free stream velocity vary in an arbitrary manner. Reduce this equation for the 2D energy flow with constant free stream velocity and constant fluid to surface temperature difference. | [15]
3 | Derive the energy equation for constant wall heat flux and fully developed flow in a circular tube. Assuming heat conduction only in the radial direction, obtain relation for temperature distribution and Nusselt number. | [15]
4 | With neat diagrams, show flow patterns on a family of wedges. Obtain similarity solution for a 2D laminar incompressible external boundary layer with constant fluid properties, while the free stream velocity varies as: \( U = Cx^m \). Discuss the effect of blowing or suction of the fluid over the surface of flow. | [15]
5 | With suitable assumptions and property rules, derive the unsteady energy equation of the turbulent boundary layer in terms of thermal eddy diffusion. | [15]
6 | With suitable assumptions, derive the heat transfer equations for laminar film-wise condensation over an inclined plane, considering also the effect of condensate subcooling. Also, obtain the non-dimensional form of the heat transfer equation. | [15]
Q.No. 1. How the level of muscular effort and muscle fatigue can be evaluated on the basis of Electromyographic recordings? Write also the formula used for the normalisation of EMG data. Also explain how the EMG signal is transformed from time domain to frequency domain and from frequency domain to time domain.

2. (a) Explain the procedure to evaluate STRAIN INDEX in a task where worker sit and perform the fitting task as shown in the following figure for a door hardware.

(b) List the different ergonomic methods for measurement of the risk of discomfort. Describe the importance of respiratory & cardiac response in the assessment of workload in Manual Material Handling tasks.

3. (a) List the level of energy expenditure for different type of tasks and also categorise those as per light, medium and heavy with suitable sketches.

(b) Explain the procedure of calculating the risk of WMSDs using Rapid Upper Limb Assessment (RULA) method with suitable example.

Contd.....2.
4  (a)  A worker unloads 24 kg bag of oranges from a conveyor and loads them onto a trolley, from where they are despatched. He loads for 3 hours per day at a rate of 4 bags per minute. The height of the conveyor is 60 cm and the height of the trolley is 100 cm. There is an angle of asymmetry of 45° and the load is held 30 cm from the body. Use the NIOSH equation to calculate the RWL and the lifting index (LI). Also comment on the safety of the task and identify the risk factors. Note: use tables given in this paper.

(b)  Explain the Rohmert's law for the endurance while performing static tasks. Also calculate the endurance time if an operator had to exert a grip force of 25 kgf while carrying a milk crate and his maximum grip force was 50 kgf.

5  (a)  What are the basic ergonomic requirement for work chair? Explain the importance and requirement of 'adaptability' and 'comfort' with suitable sketches in chair design.

(b)  How many groups, the users of wheel chair are divided in for the selection algorithm? Also draw the flow chart for the selection algorithm to assign wheel chair to the user.

6  (a)  List the different effects of vibration on human body as per respective category and the level of risks for Hand Arm Vibration (as per ISO5349) and for Whole Body Vibration (as per ISO2631). Explain the procedure in brief to calculate the risk levels.

(b)  Explain in brief the different analyses which are possible using HCAD software based on Ergonomics in Design?

7  (a)  What is tracking task? Further discuss the
i. roles of inputs and outputs in tracking.
ii. pursuit and compensatory displays in tracking.

(b)  Show the compatibility of displays and controls with respect to the combination of the movement of rotary/linear control with rotary/linear displays.

8  Explain the following in brief:
   i. Carpal tunnel syndrome
   ii. Special compatibility
   iii. Vibration dose value
Table 6.12 Values of frequency multiplier \( FM \) for use in the 1991 NIOSH equation for determining RWL.

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<tr>
<td>4</td>
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<td>0.84</td>
<td>0.72</td>
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<td>5</td>
<td>0.80</td>
<td>0.80</td>
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<tr>
<td>6</td>
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<td>0.75</td>
<td>0.50</td>
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<tr>
<td>7</td>
<td>0.70</td>
<td>0.70</td>
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<tr>
<td>8</td>
<td>0.60</td>
<td>0.60</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>9</td>
<td>0.52</td>
<td>0.52</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>10</td>
<td>0.45</td>
<td>0.45</td>
<td>0.26</td>
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<tr>
<td>11</td>
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<td>12</td>
<td>0.37</td>
<td>0.37</td>
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<tr>
<td>13</td>
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<td>0.34</td>
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<td>14</td>
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<td>0.31</td>
<td>0.00</td>
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<td>0.00</td>
<td>0.28</td>
<td>0.00</td>
<td>0.00</td>
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<td>&gt;15</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
</tbody>
</table>

Table 6.13 Values of coupling multiplier \( CM \) for use in the 1991 NIOSH equation for determining RWL.

<table>
<thead>
<tr>
<th>Coupling</th>
<th>( V &lt; 75 ) cm</th>
<th>( V \geq 75 ) cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Fair</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>Poor</td>
<td>0.90</td>
<td>0.90</td>
</tr>
</tbody>
</table>
1. Explain in detail the classification of engines generally used in automobiles. [12]

2. i) Explain and differentiate the performance characteristics of SI and CI engines. [6]
   ii) Compare the SI and CI engines on the basis of thermodynamic and operating variables. [6]

3. i) Explain the various design of combustion chambers used in DI and IDI engines. [6]
   ii) Explain (a) Three-way catalytic converter (b) particulate traps [6]

4. i) Explain the role of ignition delay in diesel engine combustion process and explain factors on which ignition delay depends. [8]
   ii) Explain individual pump and nozzle system and unit injector system with neat diagrams. [4]

5. i) Describe in detail the common rail direct injection (CRDI) system with neat sketch. [6]
   ii) Write notes on (a) thermal reactors, (b) two-way oxidation catalyst. [3]
   iii) Describe the working of Bosch (jerk type) fuel injection pump. [3]

6. i) Calculate the diameter of the fuel orifice of a four-stroke engine which develops 25 KW per cylinder at 2500 rpm. The specific fuel consumption is 0.3 Kg/KWh fuel with 30° API. The fuel is injected at a pressure of 150 bar over a crank angle of 25°. The pressure in the combustion chamber is 40 bar. Coefficient of velocity is 0.875 and specific gravity is given by

\[ \text{SG} = \frac{141.5}{(131.5 + \text{API}^\circ)} \]  [6]
   ii) Explain the homogeneous charge compression ignition (HCCI) engine. [6]

7. i) Describe the various combustion chambers used in SI engines. [4]
   ii) Explain the concept of Direct Injection (DI) in SI engine. [4]
   iii) Explain the multi-point fuel injection (MPFI) system used in SI engines. [4]
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 is fracture mechanics? Explain different types of fracture mechanisms.  
(06)

1(b)  
The stress components in a part of a structure have been calculated to \( \sigma_{xx} = 120 \text{ MPa}, \)  
\( \sigma_{yy} = 80 \text{ MPa}, \) and \( \tau_{xy} = 60 \text{ MPa} \) (all other stress components are zero). Using the  
maximum normal stress criterion, investigate material failure. The material is brittle  
and it has the ultimate strength \( \sigma_u = 150 \text{ MPa} \) in tension and the ultimate strength \( \sigma_{uc} =  
200 \text{ MPa} \) in compression.  
(06)

OR

1(b')  
The fracture toughness samples of an aluminium alloy have identical external dimensions and a thickness of 25mm. During three tests on the samples the information was obtained

<table>
<thead>
<tr>
<th>Test</th>
<th>Sample crack length (mm)</th>
<th>Applied Load (P)</th>
<th>Sample elongation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>20</td>
<td>185</td>
<td>Sample Fractured</td>
</tr>
<tr>
<td>2.</td>
<td>19.5</td>
<td>120</td>
<td>0.260</td>
</tr>
<tr>
<td>3.</td>
<td>20.5</td>
<td>120</td>
<td>0.263</td>
</tr>
</tbody>
</table>

The \( E \) and \( v \) values for Aluminium are 70GPa and 0.3, respectively. Calculate the  
fracture toughness of the material.

(06)

2.(a)  
Differentiate between Griffith approach and the approach of Irwin in the theory of fracture.  
(04)

2.(b)  
A bar of 100 x 20 \text{ mm} \) rectangular cross-section (SENT-Specimen) is loaded by a force  
of \( P = 250 \text{ kN} \) as shown in Fig. 1. Determine the critical crack length if the toughness  

Contd.....2.
is 50 MPa/m.

For the SENT specimen

\[
f\left(\frac{a}{W}\right) = \frac{1}{2} \left[ 0.752 + 2.02 \left(\frac{a}{W}\right) \right] + 0.37 \left[ 1 - \sin \left(\frac{\pi a}{2W}\right) \right]^{1/2}
\]

\[
K_i = \frac{P S}{B W^{1/2}} \cdot f\left(\frac{a}{W}\right)
\]

2'.(a) What is meant by Compliance? Derive an expression relating the strain energy release rate SERR with the End Opening \(\delta\) in a double cantilever beam DCB specimen.

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

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

Take \(\sigma = 250\) MPa; \(\sigma_{YS} = 350\) MPa; 2\(W = 210\) mm; 2\(a = 50.0\) mm.

3.(a) Differentiate between Stress intensity factor SIF and strain energy release rate SERR. Establish a relationship between them.

3.(b) What is meant by J-Integral? Derive an expression for evaluating J-Integral for a double cantilever beam DCB

4.(a) What do you understand by crack tip opening displacement CTOD? How is this considered as a fracture parameter?

4.(b) What do you understand by the phenomenon of fatigue? How is fatigue and fracture related to each other?

OR

Contd.....3.
4.(b') Differentiate between
   i. \textit{LEFM} and \textit{EPFM}
   ii. Stress Intensity Factor \textit{SIF} and Strain Energy Release Rate \textit{SERR}.

5.(a) Explain the basis of fracture based design? How it is different from conventional solid mechanics based design?

5.(b) Design a spherical pressure vessel using the
   (i) Solid mechanics based design
   (ii) Fracture mechanics based design
under the following loading condition
Internal Pressure = P = 40 MPa
Diameter of the Pressure Vessel = D = 700 MPa
Yield Strength = \sigma_y = 1460 MPa
Fracture Toughness = K_{IC} = 98.0 MPa\sqrt{m}
Compare the results.
Take, \sigma_H = p \frac{R}{2t} for Hoop stress calculation of a spherical pressure vessel.
Answer any five questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q.No. | Question | M.M.
--- | --- | ---
1(a) | Write a short note on tribology and state the savings that can be achieved using improved tribological practices. | [6]
1(b) | Discuss adhesion theory of metals with contaminated films. Write condition of gross sliding and derive the expression for the coefficient of friction. | [6]
2(a) | Write a short note on any three of the following.  
(i) Abrasive wear  
(ii) Fatigue wear  
(iii) Corrosion wear  
(iv) Fretting wear | [6]
2(b) | Describe the stick-slip phenomenon using a suitable sliding drive system. Derive the equation of motion for the driven mass for small velocity variations. Draw the acceleration, velocity and displacement curves for the mass. | [6]
3 | What is the effect of the assumption of long bearing on the analysis of the journal bearing? Hence, for lightly loaded journals with end leakage, find out the expressions for the frictional force and coefficient of friction. | [12]
4(a) | What is the advantage of pivoted slider bearing over the plane slider bearing? For a pivoted slider bearing, drive the expressions for the load capacity and the frictional force? | [8]
4(b) | Consider the following data for a pivoted shoe slider bearing and hence determine the load capacity and the corresponding frictional force.  
Length of the bearing, L = 12 cm, Width of the bearing, B = 10 cm, Speed of the... Contd....2.
journal, $U = 5 \text{ m/s}$, Height of the lubricant film at outlet, $h_2 = 0.002 \text{ cm}$, Viscosity of lubricating oil at working condition, $\mu = 25 \text{ CP}$.

For maximum load capacity and minimum frictional resistance, values from the given table may be used.

<table>
<thead>
<tr>
<th>$r$</th>
<th>1</th>
<th>1.2</th>
<th>1.3</th>
<th>1.4</th>
<th>1.5</th>
<th>1.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g_w(r)$</td>
<td>0.0265</td>
<td>0.0267</td>
<td>0.0266</td>
<td>0.0265</td>
<td>0.0263</td>
<td>0.0261</td>
</tr>
<tr>
<td>$g_f(r)$</td>
<td>4.668</td>
<td>4.656</td>
<td>4.644</td>
<td>4.633</td>
<td>4.623</td>
<td>4.624</td>
</tr>
</tbody>
</table>

5(a) Derive the expression for the flow rate of an incompressible fluid through a rectangular slot. For a hydrostatic journal bearing, derive the expression for the flow rate and load capacity.

5(b) A hydrostatic journal bearing of 101.6 mm diameter rests in a bearing of diameter 101.9048 mm. SAE 30 oil at 100 F with $\mu = 104.8 \text{ CP}$ is supplied under pressure through a groove at the lowest position of the bearing. The length of the groove is, $b = 76.2 \text{ mm}$ and the load on the bearing is 16.33 KN. What inlet pressure of oil flow rate is needed to raise the journal by (i) 0.0508 mm (ii) 0.1016 mm.

The following values of constant may be used

$$A = 140$$

$$B = 183$$

6(a) Drawing a neat sketch, explain dynamically loaded journal bearing.

(b) Drive the generalized Reynolds equation for a long dynamically loaded journal bearing. Also, obtain the dynamic pressure expression due to the rotation of the shaft

7(a) Obtain the pressure distribution and load carrying capacity for the squeeze film lubrication between two circular plates.

(b) In a journal bearing, the journal does not rotate but is approaching the bearing surface, find the time taken to move a distance from $\varepsilon = \varepsilon_1$ to $\varepsilon = \varepsilon_2$, when a constant alternating load, $P = P_0 \sin(w_0 t)$ is applied on the bearing. Here, $P_0$ is the maximum amplitude and $w_0$ is the frequency of oscillation.

(c) Write short notes on the following using suitable equation.

(i) Thermal wedge in hydrodynamic lubrication.

(ii) Aerostatic bearings.
2015-16
M.TECH. (WINTER SEMESTER) EXAMINATION
MECHANICAL ENGINEERING (MACHINE DESIGN)
MECHANICS OF COMPOSITE MATERIALS
ME 682

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)   What are the composite materials? Discuss the advantages, limitations and applications of composite materials. [04]
1 (b)   What are the basic assumptions of micro-mechanical solution for the analysis of composite? [08]

Determine the inplane shear modulus $G_{12}$ of glass/epoxy composite with properties $G_{12r} = 28$ GPa, $G_m = 1300$ MPa, $V_r = 0.6$ using both strength of materials approach and Halpin-Tsai relationship with $\xi_2 = 1$

OR

1 (b') State and derive the rule of mixture for stress and elastic modulus for a longitudinally stressed lamina in terms of usual notations. [8]

Draw and explain the stress strain relationship of the composite and its components (fibre dominated strength).

2. A high strength composite has the following elastic constants $E_1= 145$ GPa, $E_2 = 12$ GPa, $E_6 = 6$ GPa, $v_{12} = 0.25$

Determine the transformed reduced stiffness matrix for the laminae with ply angle $45^\circ$. [12]

3. Write the basic assumptions for the analysis of laminated composites. For a N-layered laminate derive [A] and [B] using resultant laminate force and moment relations. [12]

4 (a) Prove that bending-extension coupling stiffnesses are zero for a symmetric laminate. [06]

Contd.....2.
4 (b) Show that for a regular antisymmetric laminate
\[ A_{xs} = A_{ys} = D_{xs} = D_{ys} = 0 \]
Where the symbols have their usual meaning.

4 (c) Which terms of \([A]\) \([B]\) and \([D]\) matrices are zero for the following laminates?
(i) \([\alpha/-\alpha/\alpha/-\alpha]\)
(ii) \([\alpha/-\alpha/-\alpha/\alpha]\)
(iii) \([\alpha/-\alpha/-\alpha/-\alpha]\)

OR

4'. Calculate \([A]\) \([B]\) \([D]\) for \([+45/-45]\) laminate with the following laminae properties.
\[ E_1 = 140 \text{ GPa}, \ E_2 = 10 \text{ GPa}, \ E_6 = G_{12} = 5 \text{ GPa}, \ v_{12} = 0.3, \ d = 0.125 \text{ mm}. \]

5 (a) What is meant by failure and damage and what are the damage mechanisms in fibrous composites?

5 (b) Find the Tsai-Hill failure criteria for 3 D state of stress of a composite.

OR

5. (b') Write short notes on the following.
(i) Buckling of laminated beams
(ii) Methods of manufacture of fibre-reinforced composite
(iii) Fibre reinforced polymer composites
Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning. Draw neat sketches to support your answers.

Q.No.  
1(a) Define a gated pattern in metal casting.  
1(b) Figure 1 shows a symmetric end product with through hole in side faces only. Design a gated pattern for the product. Material of the pattern is aluminium and that of the end product is bismuth. Solid linear shrinkage of aluminium is 2.5% while bismuth expands on solidification at the rate of 3.3% (volumetric).

![Plan Diagram]

All the dimensions are in mm. Figure 1.

1(c) Design core for the casting. Sketch the drawing for the core designed and give all of its dimensions. Also design a suitable core box for the fabrication of core. Show the assembly of the core in the cavity of a mould box.

Contd.....2.
1(d) Give the properties of moulding sand and core sand needed for sound casting of this product. [03]

2 Design the feeding system during solidification of the casting for the following product, Figure 2. The product material is steel and its volumetric shrinkage is 4.0% during solidification. [12]

![Plan and Elevation Diagrams]

All dimensions are in mm.

Figure 2.

3 Discuss the mushy stage of freezing. Discuss the effect of mushy stage of freezing on centre-line feeding resistance. Correlate mushy stage of freezing, centre-line feeding resistance and centre-line freezing of 1.5% carbon steel in mould. With the help of iron-carbon phase diagram explain freezing of 1.5% carbon steel in a green sand mould. [12]

4 Discuss absorption of gases and dross formation in aluminium alloys. Discuss their effects on castings of aluminium alloys. Explain fluxing and flashing of aluminium melts. Also explain the techniques adopted for grain refining in castings of aluminium alloys. [12]

Contd....3.
4. Explain the effects of permeability and sand fineness of green sand on the quality of copper castings. Discuss gating design of green sand mould for copper alloy castings. Explain the effect of oxygen, hydrogen and impurities on copper melts and deoxidizing techniques adopted.  

5(a) What are the different furnaces used for steel melting? Explain open hearth furnace with the help of neat diagram. 

5(b) Discuss various casting inspection methods.  

OR

5'(a) With the help of flow diagram explain steps involved in simulation of flow of molten metal in a runner. Assume heat flux on the outer surface of runner. Discuss the effect of two different inlet velocities and pouring temperatures on temperature contours and velocity vectors obtained for mid-plane of runner. 

5'(b) Explain fluidity and shrinkage characteristics of grey cast iron. Discuss the design of gating system and riser in grey cast iron.
2014-15  
M.TECH. (WINTER SEMESTER) EXAMINATION  
(THERMAL SCIENCES)  
SOLAR ENERGY  
ME-763

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.  

1(a) Define solar constant and solar time. Discuss the attenuation of solar radiation by the earth’s atmosphere.  

1(b) Show that the daily extraterrestrial solar radiation on a horizontal surface can be given by:  

$$ H_0 = \frac{24}{\pi} L_{sc} \left(1 + 0.033 \cos \frac{360}{365} \right) (\omega_s \sin \phi \sin \delta + \cos \phi \cos \delta \sin \omega_s). $$

Clearly mention the meanings of the symbols used.

OR

Estimate the monthly average daily global and diffuse solar radiations in the month of January on horizontal surface at Agra (27° 10' N, 78° 05' E), if the average sunshine hour is 7 hours. The values of the constants a and b are 0.23 and 0.57, respectively. For January, 17th day is taken for average value of $H_0$ of the month.

Following formulae may be used:

$$ \cos \theta = \sin \delta \sin \phi \cos \beta - \sin \delta \cos \phi \sin \beta \cos \gamma + \cos \delta \cos \phi \cos \beta \cos \omega $$

$$ + \cos \delta \sin \phi \sin \beta \cos \gamma \cos \omega + \cos \delta \sin \beta \sin \gamma \sin \omega $$

$$ \delta = 23.45 \sin \left[ \frac{360}{365} (284+n) \right] $$

$$ \frac{H_g}{H_0} = a + b \frac{S}{S_{max}} \quad \text{and} \quad \frac{H_d}{H_0} = 1.354 - 1.57 K_T $$

2 Describe the construction and working of the instruments used for measurement of global and diffuse solar radiations.
3 Describe the testing procedure of a liquid flat plate solar collector and mention the curve which will be used to compare the performance of two such collectors.

OR

3'(a) Sketch three different designs of solar air heaters and give their names and label main components.

3'(b) For a conventional solar air heater, write the energy balance equations for absorber plate, air stream & bottom plate and show that the fluid temperature distribution is given by

\[
\frac{S}{U_l + T_a} - T_f = \exp \left[ -\frac{L_2 F' U_l x}{m C_p} \right]
\]

4(a) Describe the following:

(i) Solar passive heating of buildings.

(ii) Sensible heat storage systems for solar thermal energy.

4(b) Explain solar temperature. For a building exposed to solar radiation, derive the expression for the rate at which heat is transferred from the bare roof to the living space in terms of solar temperature and living space temperature. Also explain each of the terms used.