B.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING
POWDER METALLURGY
ME-406
Maximum Marks: 60
Credits: 04
Duration: Two Hours

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

Q.NO. Question M.M.
1. (a) For a cubic particle of side 3μm, a) what is the equivalent spherical surface diameter, b) the equivalent spherical volume diameter? [06]
1. (b) What similarities and dissimilarities are found between powders and a solid or a liquid? [06]
1'. Explain in detail the following methods of production of powders used in powder metallurgy:
   i) Crushing  ii) Atomization  iii) Shotting [12]

2.(a) Why is there density variation in compacted metal powders? How is it reduced? [06]
2.(b) Describe any two mechanisms of powder mixing. [06]
3.(a) Discuss the effect of particle size and particle shape on solid state sintering. [06]
3.(b) Explain liquid phase sintering. [06]
4. Explain the following terms
   i. Sizing  ii. Impregnation  iii. Infiltration [12]
5. Write short notes on any two of the following:
   I. Hot isostatic pressing, II. Continuous powder pressing, III. Powder rolling [12]
5'. Discuss in detail the applications of powder metallurgy in the following areas:
   I. Friction materials, II. Structural parts, III. Electric and magnetic components. [12]
Maximum Marks: 60
Credits: 04
Duration: Two Hours

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

Q.No. Question M.M.

1 (a) Discuss in brief the following: [06]
   i) Elementary parts of a vibrating system.
   ii) Classification of viscous damping with the practical utility of each.
   iii) Difference between Viscous and Coulomb damping.

1 (b) A shock absorber is to be designed to limit its overshoot to 10 percent of its initial displacement when released. Find the damping ratio \( \zeta_0 \) required. What will be the overshoot if \( \zeta \) is made equal to 0.5 \( \zeta_0 \).

OR

(b') A cylinder of mass \( m \) and mass moment of inertia \( J_0 \) is free to roll without slipping but is restrained by two springs of stiffnesses \( k_1 \) and \( k_2 \) and as shown in Figure 1. Find its natural frequency of vibration. Also find the value of "\( a \)" that maximizes the natural frequency of vibration. [06]

2 The landing gear of an airplane (Figure 2 (a)) can be idealized as the spring-mass-damper system shown in Figure 2 (b). If the runway surface is described by \( y(t) = y_0 \cos(\omega t) \), determine the value of damping coefficient "\( c \)" that limit the amplitude of vibration of the airplane (x) to 0.1 m. Assume \( m = 2000 \) kg, \( k = 5 \) MN/m, \( y_0 = 0.2 \) m and \( \omega = 157.08 \) rad/s. [12]

OR

cont'd 2.
An electric motor of mass $M$, mounted on an elastic foundation, is found to vibrate with a deflection of 0.15 m at resonance (Figure 3). It is known that the unbalanced mass of the motor is 10% of the mass of the rotor due to manufacturing tolerances used, and the damping ratio of the foundation is $\zeta = 0.02$. Determine the following:

(i) the eccentricity or radial location of the unbalanced mass ($e$),
(ii) the peak deflection of the motor when the frequency ratio varies from resonance.

Determine the initial conditions of the system shown in Figure 4 for which the system vibrates, (i) only at its lowest natural frequency and (ii) only at the second natural frequency, for the following data: $m_1 = m$, $m_2 = 2m$ and $k_1 = k$, $k_2 = 2k$.

Obtain the flexibility influence coefficients of the system shown in Figure 5.

OR

State the Rayleigh's Principal and discuss in brief the procedure for estimating the approximate value of fundamental natural frequency of a multi degree of freedom discrete system using Rayleigh's method.

The mass and flexibility matrix of a 3-DOF system are given by:

$$[m] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad [a] = [k]^{-1} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 2 \\ 1 & 2 & 3 \end{bmatrix}$$

Determine the Eigen values and mode shapes.

Write down the boundary conditions of the following:

(i) A uniform string or cable undergoing free transverse vibrations with one end fixed and the other end constrained elastically as shown in Figure 6.
(ii) A uniform beam undergoing free transverse vibrations with one end fixed and the other end free.
(iii) A uniform bar undergoing free longitudinal vibrations with both the ends connected to springs of stiffness $k$.

OR

Cont'd...
Derive the natural frequencies and mode shapes for the free transverse vibration of a uniform string or cable with both the ends fixed. Assume the tension '$T$' in the string to be uniform and '$\rho$' be the mass per unit length of the string.

5. (b) The mass and flexibility matrix of a 3-DOF system are given by:

\[
[m] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \text{and} \quad [k]^{-1} = [a] = \frac{1}{k} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 3 & 2 \\ 1 & 2 & 5 \end{bmatrix}
\]

Determine the fundamental natural frequency of the system using Matrix iteration method.
Maximum Marks: 60  Credits: 04  Duration: Two Hours

*Answer all the questions.*

Q.No.  Question  M.M.
1  What is the function of thermostat in a cooling system? Why is over-cooling of an engine is harmful? Explain the function of a lubricant.  [4+4+4]

*OR*

1’  What do you mean by firing order of an engine? Determine the standard firing order of an Eight Cylinder 4-Stroke In-line Engine.  [2+10]

2  An experimental 4-stroke gasoline engine of 1.7 liters capacity is to develop maximum power at 5000 rpm. The $\eta_f = 75\%$ and Air/Fuel = 14:1. Two carburetors are to be fitted and it is expected that at maximum power the air speed at the choke is 100 m/s. $C_d$ for venturi is 0.8 and $C_{dr} = 0.65$ (main jet). An allowance should be made for emulsion tube, the diameter of which can be taken as 1/3 of the choke diameter. The gasoline surface is 6 mm below the choke at this engine condition. Calculate the size of a suitable choke and main jet. The specific gravity of gasoline is 0.75. Atmospheric temperature and pressure are 300 K and 1 bar, respectively.  [12]

*OR*

2’  What is the difference between air injection and solid injection? Explain in detail with the help of suitable sketch the fuel injection system in a gasoline engine.  [4+8]

3  Describe in detail the battery ignition system with the help of suitable sketch. What is difference between a hot spark plug and a cold spark plug?  [8+4]

4  Describe the following:
   i. Propeller shaft,
   ii. Differential,
   iii. Electromagnetic clutch.  [4+4+4]

*OR*

4’  Explain with the help of suitable sketch the automatic transmission system.  [12]

5  Explain briefly:
   i. Wheel alignment,
   ii. Wheel angles,
   iii. Catalytic converter.  [4+4+4]
### 2016-17
B.TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING
POWER PLANT ENGINEERING
ME428

Maximum Marks: 60  
Credits: 04  
Duration: Two 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>Discuss Direct Energy Conversion Systems. Explain the working of thermoelectric conversion system.</td>
<td>[08]</td>
</tr>
<tr>
<td>1(b)</td>
<td>Draw sketch of Wind turbine based power plant.</td>
<td>[04]</td>
</tr>
<tr>
<td>2</td>
<td>Explain the construction and working of Babcock and Wilcox Boiler.</td>
<td>[12]</td>
</tr>
</tbody>
</table>

**OR**

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2'</td>
<td>In a cogeneration plant, the power load is 5.6 MW and the heating load is 1.163 MW. Steam is generated at 40 bar and 500°C and is expanded isentropically through a turbine to a condenser at 0.06 bar. The heating load is supplied by extracting steam from the turbine at 2 bar, which is condensed in the process heater to saturated liquid at 2 bar and then pumped back to the boiler. Compute (a) the steam generation capacity of the boiler in tonnes/h, (b) the heat input to the boiler in kW, (c) the fuel burning rate of the boiler in tonnes/h if a coal of calorific value 25 MJ/kg is burned and the boiler efficiency is 88%, (d) the heat rejected to the condenser, (e) the rate of flow of cooling water in the condenser if the temperature rise of water is 6°C. Neglect pump work.</td>
<td>[12]</td>
</tr>
<tr>
<td>3(a)</td>
<td>Briefly discuss coal handling in a thermal power plant.</td>
<td>[4]</td>
</tr>
<tr>
<td>3(b)</td>
<td>A single pass surface condenser of a small thermal power plant condenses 10 tonnes of saturated steam at 0.2 bar per hour. The rise in the water temperature is limited to 20°C and temperature difference between the steam and water at outlet is</td>
<td>[8]</td>
</tr>
</tbody>
</table>
10°C. Taking the overall heat transfer coefficient as 4 kW/m²°C, find the area of
the condenser required.

4 By choosing suitable data, design a Boiling water reactor (BWR) type of nuclear
power plant. Also, write the equations used.

OR

4'(a) Briefly discuss the working of a Fast breeder reactor based nuclear power plant.

4'(b) Discuss the working of a Gas cooled (MAGNOX) type of nuclear power plant.

5 Write brief notes on any two of the following.

(a) Compressed air energy storage method in a power plant.
(b) Define load factor, use factor, capacity factor and diversity factor. What is the
load factor of NTPC and how can we improve it.
(c) Environmental aspects of a thermal power plant operation.
Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.
Draw the vector diagram wherever necessary.

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>Define geometric, dynamic and kinematic similarities.</td>
<td>[06]</td>
</tr>
<tr>
<td>1(b)</td>
<td>Suggest the type of turbine that should be installed at a dam site where 3.7 MW is to be developed from a single unit under a head of 400m. The design r.p.m. is 500. If this turbine is tested under a head of 40m. Find the power developed and its r.p.m.</td>
<td>[06]</td>
</tr>
<tr>
<td>2</td>
<td>A Francis turbine having its inlet dia 0.64m while working under a head of 50m and running at 700 r.p.m., hydraulic efficiency is 0.96. Flow velocity through the rotor was 5.25 m/s. The outlet dia of the rotor was half the inlet dia. The discharge from the rotor was radial. Find the inlet and outlet blade angles of the rotor.</td>
<td>[06]</td>
</tr>
<tr>
<td>3(a)</td>
<td>Answer briefly:</td>
<td>[06]</td>
</tr>
<tr>
<td></td>
<td>i) Why radial curve blades are not used in centrifugal pump (CFP)?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ii) Define NPSH for CFP.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iii) Where non clog impeller of CFP are used?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>iv) Why priming is necessary in CFP?</td>
<td></td>
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<tr>
<td></td>
<td>v) Write the expression for volumetric efficiency of CFP?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>vi) What is the most important parameter which is responsible for the classification of blades of CFP?</td>
<td></td>
</tr>
</tbody>
</table>
3(b) A centrifugal pump lift water through a 10m long 150 mm dia pipe which is fitted with 90° bend. The maximum flow rate of pump is 75 ltr/sec. Find the maximum static suction head if maximum permissible vacuum is 7.5 m of water. Loss in the bend is 8 cm of water. Coefficient of friction is 4f= 0.009.

OR

3(b') Evolve theoretical head discharge curves for various outlet blade angles of impeller for centrifugal pump.

4 For an axial flow compressor with degree of reaction \( R = 0.5 \), show that fixed and moving blades are symmetrical.

OR

4' A supercharger deals with a fuel air mixture of 1 : 15.33 by mass, the volume of mixture produce by 1 kg of fuel occupying 12.7 m\(^3\) at a temperature of 0 °C and pressure of 9.83 N/cm\(^2\) abs. The supercharger compresses the mixture from a pressure of 4.8 N/cm\(^2\) abs to 9.83 N/cm\(^2\) abs, the initial temperature being -2 °C. If \( K \) for the mixture is 1.39 and the isentropic efficiency is 85%, find the power conveyed by the rotor to the gas when using 5 Kg of fuel per minute.

5(a) Derive an expression for accelerating head in the working of a reciprocating pump without air vessel on suction side.

5(b) A hydraulic lift raises a load of 8.75 tonnes at a speed of 0.5 m/s through a height of 13.5 m once in 96 sec being worked from an accumulator which is fed by a pump of efficiency of 80%. If pressure of water is 70 Kg/cm\(^2\) and efficiency of lift is 70%, find power input of pump and minimum capacity of accumulator. Neglect other losses.

OR

5(b') An intensifier of 10 cm dia ram and 1 m dia piston is connected to a press of ram dia 30 cm. Water is supplied to the intensifier from a tank 15 m above through a 5 cm dia pipe, 200 m long for which 4f = 0.032. Calculate the speed of advance of the press ram in m/hr when exerting a force of 60 tonnes.
Write few lines regarding the applications of 'operations research' in a service industry. Describe with example, the 'normalized-ratio approximation method' to solve the allocation problems.

Consider the below given data matrix for shop loading, where entries are profits when four jobs are assigned to five machines. Determine the maximum profit schedule, using assignment algorithm.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Job 1</td>
<td>9</td>
<td>11</td>
<td>15</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Job 2</td>
<td>12</td>
<td>9</td>
<td>13</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Job 3</td>
<td>8</td>
<td>11</td>
<td>14</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Job 4</td>
<td>14</td>
<td>8</td>
<td>12</td>
<td>7</td>
<td>13</td>
</tr>
</tbody>
</table>

OR

Consider the following transportation problem where matrix entries are profits. Find the optimal solution.
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>Warehouse</th>
<th>Store</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Demand</td>
<td>23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategy</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>-1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>5</td>
<td>-2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
<td>-3</td>
</tr>
</tbody>
</table>

A project expansion proposal requires an initial disbursement of $300000. The most likely outcome amounts to $12000 per month for 4 years. The minimum attractive rate of return is 11 percent per year. A risk analysis of this project proposal recognizes that the most likely cash flow has a probability of only 60 percent. A pessimistic appraisal of the future concedes returns might amount to only $5000 per month. Under the most optimistic assessment, returns could total $14000 per month. The probabilities of pessimistic and optimistic returns materializing are 15 percent and 25 percent, respectively. The duration of returns is also questionable; probabilities for 1, 2, 3 and 4 years are, respectively, 0.15, 0.25, 0.5 and 0.1. Perform Investment Analysis using acceptable investment diagram (AID) approach.

Using birth and death process, derive the relations for the parameters associated with a queuing system namely $L$, $L_\text{eq}$, $W$ & $W_\text{q}$ (Symbols have their usual meanings). Consider multiple server case M/M/s Model.

How the reliability of a product is determined? The data for a project is given in the table below. Construct a Network diagram. Find the critical path and critical path time.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Task</th>
<th>Time (in weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>AJC</td>
<td>4</td>
</tr>
<tr>
<td>1-8</td>
<td>IXZ</td>
<td>5</td>
</tr>
<tr>
<td>2-3</td>
<td>BCD</td>
<td>6</td>
</tr>
<tr>
<td>2-4</td>
<td>DYU</td>
<td>5</td>
</tr>
<tr>
<td>3-6</td>
<td>CTR</td>
<td>5</td>
</tr>
<tr>
<td>4-5</td>
<td>ECAY</td>
<td>14</td>
</tr>
<tr>
<td>5-6</td>
<td>JVU</td>
<td>0</td>
</tr>
<tr>
<td>5-7</td>
<td>HLK</td>
<td>5</td>
</tr>
<tr>
<td>5-9</td>
<td>GMN</td>
<td>7</td>
</tr>
<tr>
<td>6-9</td>
<td>FIUJ</td>
<td>10</td>
</tr>
<tr>
<td>7-9</td>
<td>KOER</td>
<td>0</td>
</tr>
<tr>
<td>8-3</td>
<td>LBAS</td>
<td>0</td>
</tr>
</tbody>
</table>
2016-17
B. TECH. (AUTUMN SEMESTER) EXAMINATION
MECHANICAL ENGINEERING
ERGONOMICS
ME-446

Maximum Marks: 60 Credits: 04 Duration: Two Hours

Answer all the questions.

Q.No. Question M.M.
1 (a) Why do you think that Ergonomics is important in Industrial World? By using Ergonomics principles, how a system can be improved? [04]
1 (b) What do you mean by displaying information? Give the detailed classification of information for different situations. [04]
1 (c) Discuss in brief the Information processing model. [04]

OR

1' (a) What are the principles of ergonomics? Further give the Ergonomics risk factors and ergonomic related injuries. [04]
1' (b) What is the unit of measurement of information? Further discuss the Redundancy. [04]
1' (c) Discuss the conditions under which auditory, visual and digital displays are used [04]
2 Discuss any three of the following: [4x3]
   (i) Musculoskeletal disorder (MSDs) and their causes,
   (ii) Mental workload and the Factors affecting the mental workload
   (iii) Cognitive abilities and cognitive perspective
   (iv) Effects of awkward postures on body parts

3 (a) What do you mean by Anthropometric data? Discuss the different types of anthropometric data and how it is used in Ergonomics? [06]
3 (b) Discuss the principles of applications of Anthropometry in Design. [06]
4 (a) How can you say that noise is harmful to human beings? Discuss the causes and effects of noise pollution. [06]
4 (b) How the Performance is affected by Vibration? Also discuss the ways to reduce the whole-body vibration (WBV). [06]
4 (a') Climate affects the performance of humans beings justify your answer. Further discuss the various Heat illnesses and individual’s differences of heat stresses.  [06]

4 (b') What do you mean by glare how it affects the human beings?  [06]

5. (a) What do you mean by human error? On what basis they are classified? Name the accidents causation theories? Further explain Arousal –Alertness theory.  [06]

5. (b) What is industrial safety? Why the personal protective equipments are used? Discuss how they are chosen for use?
1. The following data apply to a twin-spool turbofan engine, with the fan driven by low pressure (LP) turbine and compressor by high pressure (HP) turbine. Separate hot and cold nozzles are used.

Over all pressure ratio ..........25
Fan pressure ratio............1.65
Bypass ratio (B).............5
Turbine inlet temperature ......1550 K
Fan, compressor & turbine polytropic efficiency........0.9
Isentropic efficiency of propelling nozzle........0.95
Mechanical efficiency of each spool........0.99
Combustion pressure loss........1.5 bar
Total air mass flow (m)........215 kg/s

It is required to find the thrust under sea-level static conditions where ambient pressure and temperature are 1.0 bar and 288 K.

2. To illustrate the major features of external flow near the inlet, consider the simplified problem of an inlet on a semi-infinite body and derive the equation for the ratio of maximum area to inlet area.
3a. How will you match the compressor and turbine characteristics in the off-design operation of single shaft gas turbine.

3b. Write down the algorithm for matching the equilibrium running line of a gas generator.

OR

3'. The following data refers to a single shaft gas turbine running at its design speed.

<table>
<thead>
<tr>
<th>Compressor characteristics</th>
<th>Turbine characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_2/p_1$</td>
<td>$m\sqrt{T_1}/p_1$</td>
</tr>
<tr>
<td>5.0</td>
<td>32.9</td>
</tr>
<tr>
<td>4.7</td>
<td>33.8</td>
</tr>
<tr>
<td>4.5</td>
<td>34.3</td>
</tr>
</tbody>
</table>

The combustion pressure loss is 5% of the compressor delivery pressure and the ambient conditions are 1.01 bar and 288 K. Mechanical losses can be neglected. All pressures and temperatures being stagnation values. Calculate the power output when operating at a turbine inlet temperature of 1100 K.

4a. What are the desirable properties of Liquid and Solid propellants? [4]

4b. Obtain expressions for momentum thrust and characteristic velocity for a rocket nozzle. [8]

5a. What is the necessity of non-conventional propulsion systems? [4]

5b. What do you understand by electromagnetic propulsion. Explain the working of Magnetoplasmadynamic (MPD) Thruster with neat sketch. [8]

OR

5'a. Classify electric propulsion systems and what are their applications. [5]

5'b. Explain the working of Nuclear Propulsion system with neat sketch. [7]
Answer all questions.
Assume suitable data if missing.
Notations used have their usual meaning.
Take units in SI system if not specified.

Q.No.  Question  M.M.
1 (a)  Fill in the blanks  (05)
   (i) Natural boundary condition is also known as ……
   (ii)  \( \delta \left( \frac{d\theta}{dx} \right) = \ldots \)
   (iii) A homogeneous essential boundary condition is one where value of primary variable is ……
   (iv) Coefficient of weight function in boundary term of weak form is known as …… Variable.
   (v) In weak form, …… requirement of state variable is decreased as compared to governing differential equation.

1 (b)  Consider a slab of unit length having thermal conductivity \( k \). Assume one dimensional heat conduction. At \( x = 0 \), heat flow rate per unit area is given to be \( q_0 \) while at \( x = 1 \), temperature is \( \theta_1 \). The functional governing temperature distribution is
   \[
   \Pi = \int_0^1 \frac{1}{2} k \left( \frac{d\theta}{dx} \right)^2 dx - \left( \theta \bigg|_{x=0} \right) q_0.
   \]
Assume the temperature distribution of the form \( \theta = a_0 + a_1(x - 1) + a_2(x - 1)^2 \).
Use Rayleigh-Ritz method to evaluate \( a_0, a_1 \) and \( a_2 \).

OR

1 (b*) The idealized dam is shown in the following figure stands on permeable soil. Formulate the differential equation governing the steady stage seepage of water through the soil and give the corresponding boundary conditions. Use Darcy’s law for seepage flow i.e.
   \( q_x = -k \frac{\partial \phi}{\partial x} \) and \( q_y = -k \frac{\partial \phi}{\partial y} \), where \( \phi \) is total potential of seepage flow.

Contd... - 2.
2 (a) Derive the stiffness matrix for a 2 noded bar element. Take Young’s modulus $E$ as constant and cross-sectional area as $A = A_0 (2 - x/L)$, where $A_0$ and $L$ are constants. 
2 (b) Take a bar of 2 unit length as shown in following. Discretise it into 2 linear elements. Determine the global stiffness matrix and load vector. Apply displacement boundary condition and solve for nodal displacement.

3 (a) Derive the Hermite approximation functions $\phi_1$ and $\phi_2$ for two noded beam element in local co-ordinate system and plot them.
3 (b) Derive the expression for element stiffness matrix components $k_{11}^e$ and $k_{22}^e$ for two noded beam element. Take $EI$ as constant.

OR

3' Consider a beam as shown in the following figure. Discretize it into two noded 2 elements. Solve for nodal values of primary variables and get the transverse displacement and rotation at location 0.5 m from left end.

4 (a) Define local, global and natural coordinate?
4 (b) The nodal coordinates of the triangular element are shown in figure below. At the interior point $P$, the $x$-coordinate is 3.3 and $N_1 = 0.3$. Determine $N_2$, $N_3$ and the $y$-coordinate at point $P$.

4 (c) State and explain the convergence requirement of a shape function.

OR

4 (c)' Differentiate between linear strain triangular and quadratic strain triangular element. Use appropriate sketches in support of your answer.

5 (a) Figure below shows a four-noded quadrilateral. The $(x,y)$ coordinates of each node are given in the figure. The element displacement vector $\mathbf{q}$ is given as:

\[ \mathbf{q} = [0, 0, 0.20, 0, 0.15, 0.10, 0, 0.05]^T \]

Find the following:

(i) $x$ and $y$ coordinate of a point $P$ whose location in the master element is given by $\xi = 0.5$ and $\eta = 0.5$

(ii) $u$ and $v$ displacements of the point $P$.

5 (b) Derive the shape function at all the nodes for a nine noded quadrilateral element in terms of $\xi$ and $\eta$.

OR
For a three noded triangular element derive the equation, \( \varepsilon = Bq \) where, \( B \) is strain displacement matrix, \( q \) is the nodal displacement vector and

\[
\varepsilon = \begin{pmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_{xy} \end{pmatrix}
\]

Using the above derived strain displacement matrix evaluate the elemental strain displacement matrix for the structure given below.

![Triangular Element Diagram](image)

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**Formulae**

Shape function for 2 noded beam element

\[
\phi_1 = 1 - 3\left(\frac{x}{l_e}\right)^2 + 2\left(\frac{x}{l_e}\right)^3, \quad \phi_2 = -x \left(1 - \frac{x}{l_e}\right)^2
\]

\[
\phi_3 = 3\left(\frac{x}{l_e}\right)^2 - 2\left(\frac{x}{l_e}\right)^3, \quad \phi_4 = -x \left[\frac{x}{l_e}\right]^2 - \frac{x}{l_e}
\]

Elemental stiffness matrix and load vector for two noded beam element for constant \( EI \) and constant transverse distributed load \( q \) are

\[
[k^e] = \frac{2EI}{l_e^3} \begin{bmatrix} 6 & -3l_e & -6 & -3l_e \\ -3l_e & 2l_e^2 & 3l_e & l_e^2 \\ -6 & 3l_e & 6 & 3l_e \\ -3l_e & l_e^2 & 3l_e & 2l_e^2 \end{bmatrix}, \quad \{f^e\} = \frac{ql_e}{12} \begin{bmatrix} 6 \\ -l_e \\ 6 \\ l_e \end{bmatrix}.
\]