2012 – 2013
B.TECH. AUTUMN (III SEMESTER) EXAMINATION
(MECHANICAL ENGINEERING)
HIGHER MATHEMATICS
(AM – 231)
Credits: 04

Maximum Marks : 60

Note: Answer all the questions.
Start each part from a new page.

1. (a) Find the Laplace Transform of the following
   (i) \( \frac{e^{-at} - e^{-t}}{t} \)
   (ii) \( \sin h^2t \)
   (iii) \( \cos^3t \sin at \)

   (b) Use convolution theorem to evaluate

   \[ \mathcal{L}^{-1} \left[ \frac{s}{(s^2 + a^2)^2} \right] \]

   OR

   (b') Evaluate

   \[ \mathcal{L}^{-1} \left[ \frac{8s + 29}{s^2 - 12s + 32} \right] \]

   (c) Solve the Laplace Transform method, \( (D^3 - D^2 + 4D - 4)x = 68 e^{4t} \sin^2 t \), \( x_0 = 1 \), \( x_1 = -19 \), \( x_2 = -37 \).

   \[ [5 + 5 + 5] \]

2. (a) Find the values of \( a, b, c \) so that the directional derivative of \( \phi = ax^2 + by^2 + c \)\( z^2 \) at \( (1, 1, 2) \) has a maximum magnitude 4 in the direction parallel to \( x \)-axis.

   (b) (i) Find curl \( \text{curl} \vec{A} \) where \( \vec{A} = x^3 \vec{i} - 2xz \vec{j} + 2y \vec{k} \).

   (ii) Prove that for any vector \( \vec{A} \) \( \text{div} (\text{curl} \vec{A}) = 0 \).

   (c) Show that the vector field,

   \[ \vec{F} = (z^2 + 2x + 3y) \vec{i} + (3x + 2y + z) \vec{j} + (y + 2xz) \vec{k} \]

   is irrotational but not solenoidal. Also, find a scalar \( \phi \) such that \( \vec{F} = \text{grad} \ \phi \).

   \[ [5 + 5 + 5] \]

3. (a) If \( \vec{A} = (3x^2 + 6y) \vec{i} - 14yz \vec{j} + 20x^2 \vec{k} \), evaluate \( \int_C \vec{A} \cdot d\vec{r} \) from \( (0, 0, 3) \) to \( (1, 1, 1) \)

   along the straight lines from \( (0, 0, 0) \) to \( (1, 0, 0) \) then to \( (1, 1, 0) \) and then to \( (1, 1, 1) \).

   OR

   Contd…..2
(a') Verify Green's theorem in the plane for \[
\int_C \left[ (3x^2 - 8y^2)dx + (4y - 6xy)dy \right],
\]
where \(C\) is the boundary of the region bounded by \(y = \sqrt{x}\), \(y = x^2\).

(b) Use divergence theorem to evaluate \(\int_S \mathbf{F} \cdot n\,d\mathbf{s}\), where \(\mathbf{F} = x^2 \mathbf{i} + x^2y \mathbf{j} + xz \mathbf{k}\)

and \(S\) is the surface of the cylinder \(x^2 + y^2 = a^2\) bounded by \(z = 0, z = b\).

(c) Verify Stoke's theorem for \(\mathbf{F} = (x^2 + y - 4) \mathbf{i} + 3xy \mathbf{j} + (2xz + z^2) \mathbf{k}\) over the surface \(x^2 + y^2 + z^2 = 16\) above the xy-plane.

4. (a) Show that the polar form of Cauchy-Riemann equation is

\[
\frac{\partial u}{\partial r} = \frac{1}{r} \frac{\partial v}{\partial \theta}, \quad \frac{\partial v}{\partial r} = \frac{1}{r} \frac{\partial u}{\partial \theta},
\]

OR

(a') Show that the function \(u = \frac{1}{2} \log (x^2 + y^2)\) is harmonic and determine the conjugate function \(v\). Hence, or otherwise find the analytic function \(f(z) = u + iv\).

(b) Use Residue theorem to find the value of \(\int_c \frac{zd\gamma}{(z - 1)^2 (z + 1)}\) where \(C\) is the circle,

(i) \(|z| = \frac{1}{2}\)  \hspace{1cm} (ii) \(|z| = 2\).

(c) Evaluate by Contour Integration

\[
\int_a^b \frac{\cos x \, dx}{(x^2 + a^2)(x^2 + b^2)}, \quad a > b > 0.
\]
2012 – 2013
B.TECH. AUTUMN (III SEMESTER) EXAMINATION
(MECHANICAL ENGINEERING)
ECONOMICS
(HU – 203)
Credits: 04

Maximum Marks : 60

Note: All questions carry equal marks.

1. What is microeconomics? How will you distinguish it from macro-economics?
   OR

1'. Define Economics. Distinguish between static and dynamic economics.

2. Explain the concept of elasticity of demand. What are the factors which determine
   Price elasticity of demand?
   OR

2'. Explain why demand curve slopes downward from left to right?

3. What is indifference curve? Discuss its property.
   OR

3'. Discuss the important characteristic of perfectly competitive market. How the
   price is determined under perfect competition?

4. Discuss the role of small scale and cottage industries in India’s economic
devolution.

5. “Suitable use of natural resources is the key to project the environment”. Discuss.

Duration : Three Hours
2012-2103
B.Tech. Autumn (III Semester) Examination
(Mechanical Engineering)
Manufacturing Process
ME-201
(Credit: 05)

Maximum Marks: 60
Duration: Three Hours

Answer all questions.
All questions carry equal marks.

1. Explain in detail the process of centrifugal casting. Also discuss its merits and demerits and areas of application. (12)

2. Answer the following:
   (i) Why powder Metallurgy Technique is used in Mass production?
   (ii) What are cermets?
   (iii) How porous parts are fabricated through Powder Metallurgy Techniques?
   (iv) What is Hot Pressing? (12)

OR

2. Write notes on:
   (i) Infiltration
   (ii) Impregnation
   (iii) Compacting (12)

3. (i) What are polymer additives?
   (ii) List some important useful properties of plastics.
   (iii) Differentiate between "Themosets" and "Thermoplastics"?
   (iv) List some of the important uses of "Phenol formaldehyde" and "Urea formaldehyde". (12)

OR
3. Write notes on:

(i) Celendering
(ii) Injection Molding
(iii) Machining of Plastics

4. Explain with the help of sketches TIG and MIG welding processes, their relative merits and demerits and important areas of application.

OR

4. (i) Explain the term soft solder and hard solder.
(ii) List some of the applications of spot welding.
(iii) Explain three types of flames used in gas welding.
(iv) Explain the term “adhesive bonding.”

5. Define the following processes

(i) upsetting
(ii) Drawing down
(iii) Swaging
(iv) Bending
(v) Coining
(vi) Spinning
1. Explain hydrostatic stress, direction cosines and pure shear stress. The state of stress at a point is given by
\[ \begin{align*} 
\sigma_{xx} &= 37.2 \text{ MN/m}^2 \\
\sigma_{yy} &= 78.4 \text{ MN/m}^2 \\
\sigma_{zz} &= 149 \text{ MN/m}^2 \\
\tau_{xy} &= 68 \text{ MN/m}^2 \\
\tau_{yz} &= -18.1 \text{ MN/m}^2 \\
\tau_{zx} &= 32 \text{ MN/m}^2 
\end{align*} \]
Calculate the normal, shear and resultant stresses on a plane whose normal makes an angle of 45° with the X axis and 71° with the Y axis. OR

1'.(a) Derive the stress equations of equilibrium in cylindrical coordinates and simplify it to the following form for the case of axial symmetry with the coordinate axes coinciding with principal stress directions,
\[ \frac{\partial \sigma_{rr}}{\partial r} + \frac{(\sigma_{rr} - \sigma_{\theta\theta})}{r} = 0 \]
\[ \frac{\partial \sigma_{\theta\theta}}{\partial \theta} = 0 \]
\[ \frac{\partial \sigma_{zz}}{\partial z} = 0 \]
(b) The strains measured by a 3 element rectangular rosette are shown in Fig.1. Find the principal strains by using transformation equations. Also find the principal strains graphically and compare the results.

2. (a) State the generalized Hook's law and show that for an anisotropic elastic material the maximum number of elastic constants is 21 only. Also show that for isotropic material it is 2.
(b) A grinder wheel has external and internal diameters as 300mm and 25mm respectively. If the thickness of the wheel at the outer radius is 25mm, what should be the thickness at the inner radius for a uniform allowable stress of 10 MPa at 2800 rpm? Take density of the wheel material as 2700 kg/m³.

3. (a) Define force fits, and prove that the radial and hoop stresses for a thick cylinder are:
\[ \sigma_r = A - \frac{B}{r^2} \]
\[ \sigma_h = A + \frac{B}{r^2} \]
3.(b) A 3 m long aluminium-alloy tube, of 150 mm outside diameter and 5 mm wall thickness, is closely wound with a single layer of 2.5 mm diameter steel wire at a tension of 400 N. It is then subjected to an internal pressure of 7 MN/m².

(i) Find the stress in the tube before the pressure is applied.
(ii) Find the final stress in the tube.

\[ E_A = 70 \text{ GN/m}^2; \, \nu_A = 0.28; \, E_G = 200 \text{ GN/m}^2 \]

4.(a) Derive the basic differential equation for the deflection of beams and thus using direct integration method find the maximum slope and maximum deflection of a cantilever beam with uniformly distributed load across the whole span.

(b) A uniform beam, built-in at each end, is divided into four equal parts and has equal point loads, each \( W \), placed at the centre of each portion. Find the deflection at the centre of this beam and prove that it equals the deflection at the centre of the same beam when carrying an equal total load uniformly distributed along the entire length.

OR

4'. A continuous beam ABCDE rests on five simple supports A, B, C, D and E. Spans AB and BC carry a uniformly distributed load of 60 kN/m and are respectively 2 m and 3 m long. CD is 2.5 m long and carries a concentrated load of 50 kN at 1.5 m from C. DE is 3 m long and carries a concentrated load of 50 kN at the centre and a uniformly distributed load of 30 kN/m throughout the span DE. Draw the Bending Moment and Shear Force diagrams for the beam.

5.(a) Two shafts, one of steel and the other of phosphor-bronze, are of the same length and are subjected to equal torques. If the steel shaft is 25 mm diameter, find the diameter of phosphor-bronze shaft so that it will store the same amount of energy per unit volume as the steel shaft. Also determine the ratio of the maximum shear stresses induced in the two shafts. Take the modulus of rigidity for phosphor bronze as 50 GN/m² and for steel as 80 GN/m².

(b) State and prove Castigliano's first theorem.

\[ e_C = 400 \times 10^{-6} \]
\[ e_A = 800 \times 10^{-6} \]

[Figure 1]

\[ 45^\circ \]

\[ \sigma_C = 400 \times 10^6 \]
\[ \sigma_A = 800 \times 10^6 \]
Maximum Marks: 60

Answer all questions.
All questions carry equal marks.

1. Answer the following

   (i) What are the demerits associated with metallic patterns?

   (ii) What is the effect of permeability on the quality of casting?

   (iii) What is the function of a riser?

   (iv) Explain the term "directional solidification"?

   (v) What are requirements of an ideal gating system?

   (vi) Differentiate between expandable moulds and permanent moulds? (12)

OR

1' (a) Explain in detail step by step procedure of die casting. Also discuss its merits and demerits and areas of application. (6)

   (b) List the various defects that occur in sand castings and state their probable causes and effective remedies? (6)

2. Explain in detail the primary processes used in manufacturing articles from metal powders? (12)

OR

2' (a) What is the significance of Non-conventional machining processes and how are they classified? (4)
(b) Explain in detail the process of “Water Jet Machining”. Also discuss its merits and important applications. (8)

3. Write detailed notes on
(a) Blow Molding
(b) Transfer Molding (12)

4. (i) Discuss three types of flames used in gas welding?
(ii) Explain the principle of resistance welding?
(iii) Differentiate between “soldering” and “Brazing”?
(iv) What are the causes and remedies of “cracks” in welded joints? (12)

5. (i) What is the significance of “recrystallization temperature”?
(ii) Define the terms “Blanking” and “Punching”?
(iii) Differentiate between “hot working” and “cold working”?
(iv) Discuss the advantages of “Press Forging” over “Drop Forging”? (12)

OR

5'. Write detailed notes on any two
(i) Extrusion
(ii) Deep drawing
(iii) Sheet metal working (12)
Assume any suitable data if missing.

Q1-a. A consulting firm rents cars from three agencies, 20% from agency D, 20% from agency E, and 60% from agency F. If 10% of the cars from D, 12% of the cars from E, and 4% of the cars from F have bad tires, what is the probability that the firm will get a car with bad tires?

Q1-b. During one stage manufacturing of integrated circuit chips, a coating must be applied. If 70% of chips receive a thick enough coating, use Table to find the probabilities that among 15 chips

- At least 12 will have thick enough coatings.
- Exactly 10 will have thick enough coatings.

Q1-c. If two independent samples of sizes n1=16 and n2=8 are taken from a normal population, what is the probability that the variance of the second sample will be atleast 2.4 times the variance of the first sample?

OR

Q1'-a. In the inspection of in plate produced by a continuous electrolytic process, 0.2 imperfection is spotted on the average per minute. Find the probabilities of spotting

- One imperfection in 3 minutes
- At least two imperfections in 5 minutes

Q1'-b. If two random variables have the joint density

\[ f(x, y) = \begin{cases} 
\frac{6}{5}(x+y^2) & \text{for } 0 < x < 1, 0 < y < 1 \\
0 & \text{otherwise}
\end{cases} \]

Find the probability that 0.2 < x < 0.5 and 0.4 < y < 0.6.

Q1'-c. A random sample of 10 observations is taken from a normal population having the variance \( \sigma^2 = 42.5 \). Find the approximate probability of obtaining a sample standard deviation between 3.14 and 8.94.

Q1'-a. Suppose the four observations are 67, 48, 76, 81. Construct a normal-score plot to verify the normality of the data.

OR

Q1'-a. A random sample of 100 automobile owners shows that, in the state of Virginia, an automobile is driven on the average 23,500 km per year with a standard deviation of 3900 km. Construct a 95% confidence interval for the average number of kilometres an automobile is driven annually in Virginia.

Q1'-b. Raw material used in the production of synthetic fiber is stored in a place which has no humidity control. Measurements of the relative humidity in the storage place and the moisture content of a sample of raw material (both in percentage) on 12 days yielded the following results:

<table>
<thead>
<tr>
<th>Humidity (X)</th>
<th>42</th>
<th>35</th>
<th>50</th>
<th>48</th>
<th>43</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (Y)</td>
<td>12</td>
<td>08</td>
<td>14</td>
<td>11</td>
<td>09</td>
</tr>
</tbody>
</table>

- Fit a straight line by the method of Least Square
- Find a 99% confidence interval for the mean moisture content of the raw material when the humidity of the storage place is 40%.
Q3-a. Write down the general differential equation describing the dynamic response of a second order measuring instrument and state the expressions relating the static sensitivity, undamped natural frequency and damping ratio to the parameters in this differential equation. Sketch the instrument response for the cases of heavy damping, critical damping and light damping for step input signal, and state which of these is the usual target when a second order instrument is being designed.

Q3-b. Consider a first order system \((1+\alpha D)x_0 = x_1\),
   - if \(x_1 = \alpha t + \beta t^2\) then the complimentary function is.
   - If \(x_1 = \alpha e^{-\beta t}\) then the particular solution is.

Q3-c. Define briefly the following static performance characteristics of instruments:
   - Tolerance
   - Backlash
   - Static sensitivity to disturbance
   - Hysteresis

OR

Q3'-a. Formulate the system equation for "Liquid in glass thermometer" relating the output signal in the form of displacement of liquid in the capillary tube and the input temperature of the fluid, surrounding the bulb of thermometer.

Q3'-b. Differentiate between the following types of instruments with the help of suitable examples:
   - Null and Deflection type of instruments
   - Dumb and Intelligent type of instruments
   - Active and Passive type of instruments

Q3'-c. A load cell is calibrated in an environment at a temperature of 21°C and has the following deflection/load characteristic:
   
<table>
<thead>
<tr>
<th>Load (kg)</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection (mm)</td>
<td>0.0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

   When used in an environment at 35°C, its characteristic changes to the following:
   
<table>
<thead>
<tr>
<th>Load (kg)</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflection (mm)</td>
<td>0.2</td>
<td>1.3</td>
<td>2.4</td>
<td>3.5</td>
<td>4.6</td>
</tr>
</tbody>
</table>

   (a) Determine the sensitivity at 21°C and 35°C.
   (b) Calculate the total zero drift and sensitivity drift at 35°C.
   (c) Hence determine the zero drift and sensitivity drift coefficients (in units of \(\mu m/°C\) and \(\mu m\) per kg/°C).

Q4-a. Discuss 4 practical applications of Capacitive transducers supported with neat diagrams.

Q4-b. Describe the working of LASER Printer with the help of a diagram.

Q4-c. Discuss briefly the Resistance Ladder type Digital to Analogue converter with the help of diagram.

Q5-a. Discuss briefly with the help of diagrams any two (2) of the following:
   - Resistance Temperature Detectors and Thermistors
   - McLeod Pressure Gauge
   - Obstruction type flowmeters

Q5-b. Write brief notes on the following:
   - Prony brake used for Torque and Power measurements
   - Strain Gauge and its application for Bonding force and Axial force measurement.
2012-2013
III Semester B. Tech. Examination
Mechanical Engineering
Applied Thermodynamics (ME 221)
Maximum Marks: 60 Credits: 04 Duration: Three Hours

Attempts all Questions. All Questions are of Equal Marks. Assume suitable value of data if not given already. Use of Property Tables is allowed. All Symbols have usual meaning.

1. Prove that:
   i. \( ds = C_v \frac{dT}{T} + (\frac{\partial p}{\partial T})_v dv \)
   ii. \( \mu_k = \frac{1}{C_p} [T \left( \frac{\partial v}{\partial T} \right)_p - v] \)

   where symbols have usual meanings.

OR

1'. (a) Discuss in detail significance of equations of state for real gases. Find the expression of Van der Waals equation of state in terms of reduced coordinates \( P_r, V_r \) and \( T_r \) and show that at critical point \( Z_c = 3/8 \)
(b) Carbon dioxide enters an adiabatic nozzle at 8 MPa and 450 K with a low velocity and leaves at 2 MPa and 350 K. Using the generalized enthalpy chart, determine the exit velocity of the carbon dioxide.

2. (a) Prove that \( dh = C_v dT + \left[ v - T \left( \frac{\partial v}{\partial T} \right)_p \right] dp \) and show that for Vander Waal's equation, the following relation applies: \( h_2 - h_1 = (P_1v_2 - P_1v_1) + a \left( \frac{1}{v_1} - \frac{1}{v_2} \right) \)

(b) Steam having a volume of 19.5 m³ is compressed reversibly in a closed system from 310°C and 66 bar till it becomes dry saturated at 340°C. Using generalized compressibility chart, determine the mass and the final volume.

3. (a) Describe in detail the concept of wet bulb temperature of an air-water vapour mixture. Derive the expression for the measurement of specific humidity by using an adiabatic saturator. An stream of air has DBT = 22°C and DBT = 17°C flowing in to an adiabatic saturator under steady state condition and leaving the saturator fully saturated at 17°C. Find the value of specific humidity of the air stream by using steam tables. Also show the process on a Psychrometric Chart.

(b) A 1 kg sample of moist air initially at 21°C, 1 bar, and 70% RH is cooled to 5°C while keeping the pressure constant. Determine (i) the initial specific humidity, (ii) the dew point temperature, in °C and (iii) the amount of water vapour that condenses, in kg.

OR

3'. (a) An analysis of mixture of gases yields the following composition on a volumetric basis: \( N_2 \) 70%, \( CO_2 \) 15%, \( O_2 \) 11%, \( CO \) 4%. Determine: (i) the composition of this mixture on a mass basis (ii) the mass of 0.2 m³ of this mixture at a condition of 100 kPa, 20 °C (iii) the heat transfer required to heat the mixture at constant volume from the initial state to 150 °C.
(b) A stream consisting of 142 m³/min of moist air at a temperature of 5°C and a humidity ratio of 0.002 kg (vapour)/kg (dry air) is mixed adiabatically with a second stream consisting of 425 m³/min of moist air at 24°C and 50% RH. The pressure is constant throughout at 1 bar. Using the psychrometric chart, determine (i) the humidity ratio and (ii) the temperature of the exiting mixed stream, in °C.

4 (a) A cold storage is operating with cooling load of 5 kW at a low temperature of -15°C. It uses ammonia as the refrigerant. Assuming a standard vapour compression refrigeration cycle with a condenser at 20°C. The vapour is dry saturated at the exit of evaporator and there is no under-cooling, find (i) the flow rate of the ammonia needed, (ii) the power required to drive the compressor, (iii) the COP.

(b) Air enters the compressor of an ideal Brayton refrigeration cycle at 1 bar, 270 °K, with a volumetric flow rate of 1.4 m³/sec. If the compressor pressure ratio is 3 and the turbine inlet temperature is 300 °K, determine (i) the net power input, in kW, (ii) the refrigeration capacity, in kW, (iii) the COP.

5 (a) Explain the concept of volumetric efficiency of a reciprocating compressor. A two stage reciprocating compressor with ideal inter-cooling and without clearance volume is following polytropic law for compression and expansion process, prove that the expression for the minimum compression work is: \( W_c = \frac{m_s}{\gamma - 1} \left( \frac{P_2}{P_1} \right)^{\gamma} - 1 \). Where symbols have their usual meaning and assume that the intermediate pressure for minimum work is \( \sqrt{P_1P_2} \).

(b) A two stage reciprocating compressor fitted with an ideal intercooler takes in 20 Kg of air per minute at 20°C and 0.1 MPa and delivers it at 2.0 MPa. The polytropic index of compression is 1.2. Find the minimum compression work and the amount of heat rejected in the intercooler. Draw P-V diagram.
2012-2013
B. TECH AUTUMN SEMESTER EXAMINATION
(MECHANICAL ENGINEERING)
FLUID MECHANICS - I
(ME-231)
CREDITS: 04

MAXIMUM MARKS: 60
DURATION: THREE HOURS

NOTE: Answer all the questions, symbols have their usual meaning.
Assume suitable any missing data.
Use of gas tables, flow functions for computation of compressible flow.
Moody's diagram and sheets of mathematical identities is permitted.

1(a). The velocity distribution for laminar flow between the parallel plates is given by
\[
\frac{u}{u_{\text{max}}} = 1 - \left( \frac{2y}{h} \right)^2
\]
where 'h' is the distance separating the plates and the origin is placed midway between the plates. Consider a flow of water at 15°C, with \( u_{\text{max}} = 0.3 \text{m/s} \) and \( h = 0.5 \text{mm} \). Calculate the shear stress on the upper plate by the fluid and give its direction. Sketch the variation of shear stress across the channel.

1(b). Consider an open circular cylinder of radius 'R', height 'H' initially filled with some liquid to a height 'h'. If the cylinder is rotated about its axis (oriented along gravity) at a steady rotation rate 'ω', determine
i. Critical speed 'ω_c' that just prevents spilling of liquid as a function of (h/H) for h/H < \( \frac{1}{3} \)
ii. The speed 'ω_1' that causes the center of the base to be just exposed to the atmosphere for h/H < \( \frac{1}{3} \)

2(a). Given a velocity field \( (\text{in m/s})\ V = x^2\hat{i} + 2xy\hat{j} \) and the temperature field \( T \) (in °C) = 3xyt, with \( x \) and \( y \) in m and \( t \) in s. Determine with working:

i. if the flow field is incompressible.
ii. if the flow field is irrotational.
iii. acceleration at the point \( (1\text{m}, 1\text{m}) \) at \( t = 1 \text{s} \).
v. the rate of change of temperature with time of a particle moving in the flow at \( (1\text{m}, 1\text{m}) \) and \( t = 2\text{s} \).

2(b). The figure below (figure 1) shows path-lines of particles released at A \( (0,0) \) at a gap of 1 second \( (0 \leq t \leq 10) \). The time indicated in the figure shows the time at which the particle was released.

i. Explain giving reasons if this flow is steady or unsteady.
ii. Sketch the figure and on it draw a qualitative pattern of the streak-line of particles passing through \( (0,0) \) observed at 6s.
2'(a). Consider a steady, viscous, incompressible, two-dimensional radial flow through a diverging passage formed by two plates of width 'w' into the paper as shown in figure below (figure 2). Since the flow is radial, \( \mathbf{V} = v(r, \theta) \mathbf{e}_r \).

i. Using continuity, show that the steady radial velocity can be expressed in the general form \( v = f(r) r \), where \( f \) is some function of \( \theta \) only.

ii. Using no-slip show that \( f(\pm a) = 0 \)

iii. From the geometry, one can argue that the distribution of the radial velocity must be symmetric about the passage centerline \( \theta = 0 \). Thus, prove that for the function \( f(\theta) \), all odd derivatives at \( \theta = 0 \) must vanish.

2'(b). The velocity potential in a flow is \( \phi = xy + x^2 - y^2 \). Find the stream function for this flow. Also plot the streamlines.

3(a). Given a flow with circular streamlines (anticlockwise) as shown in figure below (figure 3). Explain with reasons if

i. \( \frac{dp}{d_1} = 0 \)?

ii. Assuming steady, incompressible and inviscid flow can pressure be determined between points A and B using Bernoulli's Equation?

iii. Assuming steady, incompressible and inviscid flow can pressure be determined between points A and C using Bernoulli's Equation?
3(b). A gas-filled pneumatic strut in an automobile suspension system behaves like a piston-cylinder apparatus (figure 4). At one instant when the position is $L=0.15\text{m}$ away from the closed end of the cylinder, the gas density is uniform at $\rho = 18\text{kg/m}^3$ and the piston begins to move away from the closed end at $V = 12\text{ m/s}$. The gas motion is 1D and proportional to distance from the closed end; it varies linearly from zero at the end to $u = V$ at the piston.

i. Evaluate the rate of change of gas density for a fluid particle at this instant.

ii. Obtain an expression for the average density as a function of time.

\[ u = \frac{Vx}{L} \]

\[ \rho = 18\text{ kg/m}^3 \]

\[ V = 12\text{ m/s} \]

\[ \text{figure 4} \]

3(c). When a uniform stream flows past an immersed thick cylinder, a broad low-velocity wake is created downstream, idealized as a V shape in figure 5. Pressure $p_1$ and $p_2$ are approximately equal. If the flow is two-dimensional and incompressible, with width $b$ into the paper, derive a formula for the drag force $F$ on the cylinder. Rewrite your result in the form of a dimensionless drag coefficient based on body length $C_D = F/pbL U^2$.

\[ \text{figure 5} \]

OR

3'(c). Water flows at $0.05\text{ m}^3/\text{s}$ through a Y connector shown and splits into two streams having equal velocity. The pressure at point 1 is $2 \times 10^5\text{ Pa}$. Find the $x$ and $y$ components of force required to hold the Y connector in place (figure 6). Neglect the weight of the liquid and connector. The connector is connected to pipes at both inlets and both the exits.
4(a) An engineer who took college fluid mechanics on a pass-fail basis has placed the static pressure hole far upstream of the stagnation probe, as in Figure 7, thus contaminating the pitot measurement ridiculously with pipe friction losses. If the pipe flow is air at 20°C and 1 atm and the manometer fluid is Meriam red oil (SG = 0.827), estimate the air centerline velocity for the given manometer reading of 16 cm. Assume a smooth-walled tube with a Darcy's friction factor $f = 0.02$.

4(b) The pipe flow in Figure 8 is driven by pressurized air in the tank. What gauge pressure $p_2$ is needed to provide a 20°C water flow rate $Q = 60 m^3/h$?

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Answer any two of the following:

5(a) A converging-diverging nozzle is designed to operate with an exit Mach number of 1.75. The nozzle is supplied from an air reservoir at 6.9 MPa. Assuming one-dimensional flow, calculate:

i. Maximum back pressure to choke the nozzle

ii. Range of back pressure over which a normal shock will appear in the nozzle

iii. Back pressure for the nozzle to be perfectly expanded to the design Mach number

iv. Range of back pressure for supersonic flow at the nozzle exit plane.
5(b). Air flows through a convergent-divergent nozzle from a large reservoir in which the pressure and temperature are maintained at 700 kPa and 60°C respectively. The rate of air flow through the nozzle is 1 kg/s. On the exit plane of the nozzle the stagnation pressure is 550 kPa and the static pressure is 500 kPa. A shock wave occurs in the nozzle and the flow can be assumed to be isentropic everywhere except through the shock wave. Find the nozzle throat area, the Mach number before and after the shock, the nozzle areas at the point where the shock occurs and on the exit plane, and the air density on the exit plane of the nozzle.

5(c). The orientation of a hole can make a difference. Consider holes A and B as shown in figure 9, which are identical but reversed. For the given air properties on either side, compute the mass flow through each hole and explain why they are different.