DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
HUNTSVILLE, AL 35899

INSTRUCTIONAL PAMPHLET CONCERNING PRELIMINARY EXAMINATION FOR STUDENTS PURSUING THE PH.D. DEGREE IN EITHER MECHANICAL OR CHEMICAL ENGINEERING

ISSUED BY

MAE DEPARTMENT
GRADUATE STUDIES COMMITTEE

REVISED OCTOBER 2007

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
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Information Concerning the Ph.D. Preliminary Examination

The Preliminary Examination (or Entrance Exam) is a written test of a student's capability to successfully pursue the Ph.D. degree and aids in developing a program of study appropriate for the student. Candidates for the Ph.D. degree must take the preliminary exam before completing no more that 12 hours of graduate course work at UAH after being admitted to the Ph.D. program in the MAE Department. Failure to take the exam within the prescribed period will result in their admission to the MAE Ph.D. program being voided.

The examination will be administered in accordance with Procedure for Ph.D. Preliminary Examination as set forth on pages 23 and 24 of the MAE Graduate Student Handbook and listed below. A student who fails this examination may repeat it for the second time. The examination may not be taken more than twice. However, in extenuating circumstances a student may submit a petition to the Chairman of the MAE Department, with the signed concurrence of a faculty member, for a third attempt. The Graduate Program Committee will review this petition for approval or disapproval.

FORMAT OF PRELIMINARY EXAMINATION

The exam is conducted on the last Saturday in October and either the last Saturday in March or the first Saturday in April, each year, from 8:00 am until 12:00 noon. The exam is given in room N225 of Technology Hall.

The exam is conducted in a closed book, closed note format. Copies of steam tables will be provided for those taking exams in thermodynamics. Tables for other exams will be provided as required. Candidates should bring a hand held calculator. Students should report to the exam proctor at least 15 minutes before the start of the portion of the exam they are taking. Be prompt and follow the instructions provided at the time of the exam precisely.

Time allocations:

8:00 – 10:00 am	Exam in major area
10:00 – 11:00 am	Exam in non-mathematics minor
11:00 – 12:00 pm	Exam in mathematics minor area

PROCEDURE FOR PH.D. PRELIMINARY EXAMINATION

1. The Ph.D. Preliminary Examination will be given on the last Saturday of October and either the last Saturday in March or the first Saturday in April each year. The Graduate Program Committee Chair will be responsible for executing the following procedure.

2. A written announcement will be posted two months prior to the examination date.

3. Any graduate student desiring to take the Preliminary Examination shall notify the Mechanical and Aerospace Engineering Department, in writing, no later than one month prior to the exam, indicating a major and a minor area, chosen from the following:

Subject Areas:	Course Work involved:
Dynamics	MAE 272 MAE/CE 561
Experimental Mechanics	MAE/CE 370, MAE/CE 577
Fluid Mechanics	MAE 310, MAE 520, MAE 651
Heat Transfer	MAE 450, MAE 643
Solid/Structural Mechanics	MAE/CE 370, MAE/CE 574
Thermodynamics	MAE 342, MAE 641
Mathematics	MAE 692, 671
Chemical Engineering	CHE 344, CHE 649, CHE 658

   CHE students may choose Chemical Engineering as a major. However, a minor area must be chosen from the other subject areas listed above.

   In addition to examinations in the major and minor areas selected, all Ph.D. candidates must pass an examination in a second minor area of mathematics. (MAE 692 and 671)

4. The Graduate Program Committee Chair will designate one faculty member to coordinate each area. This faculty member will be primarily responsible for soliciting, selecting, and grading problems in his/her area. All faculty members are encouraged to participate in this process.

5. Problems for the examination will be selected from upper level undergraduate and first year graduate level courses (600 level or below).

6. There will be 6 problems in each area. All 6 problems must be attempted in the designated major area. A student must work any 3 out of the 6 problems in the minor area.

7. Each of the 6 problems in the major and minor areas will be of equal weight and selected in such a manner that it will take approximately 20 minutes for the average student to

complete. A total of two hours will be scheduled for the major area. One hour will be scheduled for working problems in the minor area (3 out of 6 problems).

8. The mathematics area will consist of 3 out of 6 problems and will last one hour. Selection of problems will be made as follows: Four (4) problems from MAE 692 - Graduate Engineering Analysis I. The student must solve two (2) of the four problems from MAE 692. In addition two (2) problems from MAE 671 - Continuum Mechanics will be given and the student must solve one (1) of these two problems. Each problem will take approximately 20 minutes for the average student to complete.

9. A score of 60% or above will be considered as passing.

10. Students failing to appear for the exam without an acceptable excuse will receive an automatic failure.

Listing of Topics for Preliminary Examination in Mathematics Including Continuum Mechanics

Topics to be covered on the Preliminary Examination in Mathematics are taken primarily from those topics covered in the graduate courses: MAE 692 – Graduate Engineering Analysis I and MAE 671 – Continuum Mechanics.

1. First-order linear and nonlinear ordinary differential equations.

2. Second-order homogenous and inhomogeneous, constant and variable coefficients ordinary differential equations.

3. Frobenius method of solution for ordinary differential equations.

4. Sturm-Liouville problem and its solution.

5. Laplace transforms as applied to the solution of ordinary differential equations.

6. Solution of first-order partial differential equations using the method of characteristics.

7. Solution of partial differential equations using separation of variables.

8. The heat equation and the wave equation.

9. Fourier Series and Fourier integrals.

10. Tensor analysis
    - Ability to use tensor notation in vector and matrix products.
    - Relations between domain and boundary surface integrals through tensorial operations.
    - Coordinate transformations through tensorial operations.
    - Divergence and curl of vectors through tensorial operations.

Sample Mathematics Exam Problems (Including Continuum Mechanics)

1. Solve the wave equation, $\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2} = 0$, for an unconstrained bar, i.e., with free-free boundary conditions (i.e. $\frac{\partial u}{\partial x} = 0$ at $x = 0, l$) in axial vibration with the following initial conditions:
   $u(x,0) = \frac{1}{2}\cos\frac{\pi x}{l}$ and $\left.\frac{\partial u}{\partial t}\right|_{(x,0)} = 0$, where $c = \sqrt{\frac{E}{\rho}}$ and l is the length of the bar.

2. Using the index notation, verify the following vector identities:

$$\nabla \times \nabla \times \vec{A} = \nabla(\nabla \cdot \vec{A}) - \nabla^2 \vec{A}$$

3. Let the coordinate transformation be carried out successively by first rotating counterclockwise 30° about x_3 axis, then rotating clockwise 60° about the x_2' axis. Calculate the components of $\vec{A} = (2,2,1)$ in terms of the new coordinates x_i''.

4. Solve the following differential equation

$$\frac{dy}{dx} = \frac{1}{6e^y - 2x}$$

5. Solve the following partial differential equation. Give your answers in the form of $F(C_1, C_2) = 0$, where $C_1 = U_1(x,y,z)$ and $C_2 = U_2(x,y,z)$ are functions of (possibly) x, y and z.

$$xz\frac{\partial z}{\partial x} + yz\frac{\partial z}{\partial y} = xy$$

6. Solve the given set of simultaneous equations by using variation of parameters.

$$\begin{cases} \dfrac{dy_1}{dt} = 2y_1 + 2y_2 + e^t \\ \dfrac{dy_2}{dt} = -2y_1 - 3y_2 + e^t \end{cases}$$

   These have the homogeneous solution of $\begin{cases} y_1 = -2c_1 e^t + c_2 e^{-2t} \\ y_2 = c_1 e^t - 2c_2 e^{-2t} \end{cases}$.

Listing of Topics for Preliminary Examination in Dynamics

Topics to be covered on the Preliminary Examination in Dynamics are taken primarily from those topics covered in the undergraduate course MAE 272 - Dynamics and the graduate course MAE 561 - Vibrations of Elastic Systems.

1. Derivation of equation of motion (EOM) for a particle in rectangular Cartesian coordinates, cylindrical coordinates, or tangent and normal components

2. Principle of work and energy.

3. Kinetics of particles involving impact.

4. Derivation of EOM for a rigid body in plane motion.

5. Derivation of EOM for a single-degree-of-freedom (SDOF) vibration system.

6. Analysis of a SDOF system subjected to harmonically excited vibration, e.g., rotating unbalance, support motion, and vibration isolation

7. Analysis of a SDOF system in transient vibration.

8. Derivation of EOM for a multi-degree-of-freedom (MDOF) vibration system.

9. Modal analysis for solving coupled equations of motion for a MDOF system.

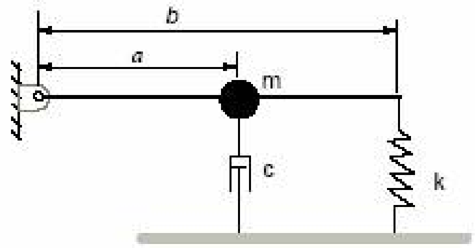
10. Derivation of EOM for a system of rigid bodies using Lagrange's equation.

11. Derivation of EOM for a continuous system (vibrating string, rod in longitudinal vibration, shaft in torsional vibration, and beam in flexural vibration).

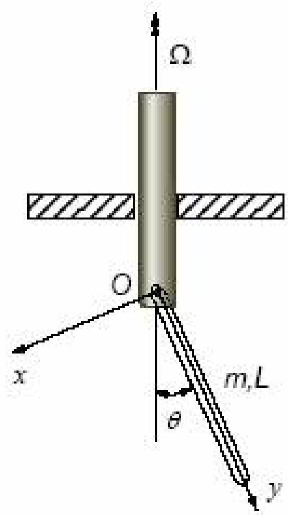
12. Natural frequency and normal mode of a continuous system.

Sample Dynamics Exam Problems

1 Derive the equation of motion for the system shown in the following and determine the natural frequency of damped oscillation and the critical damping coefficient, assuming small oscillation.



2 A thin uniform bar of mass m and length L is connected by a pin joint at one end to a vertical shaft which rotates at a constant rate Ω as shown in the following figure. Derive the differential equation of motion for the system in terms of the angle θ, and determine the natural frequency of the oscillation for $\theta << 1$.

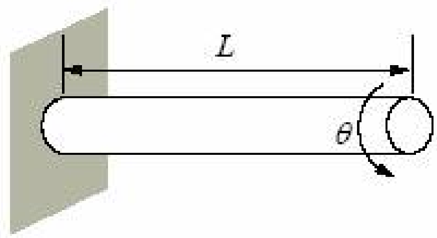


3. Find the free response of the following two-degree-of freedom system using modal analysis method. Give answers in terms of natural frequencies, the corresponding mode shapes (give schematics), and the time response of the coordinates.

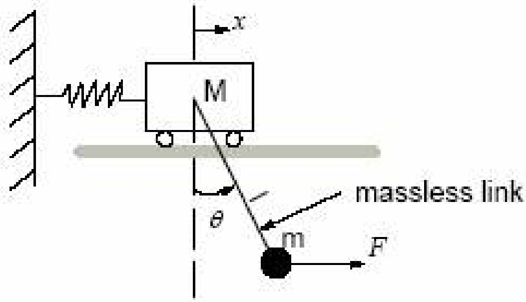
$$[m]=\begin{bmatrix}2 & 0\\ 0 & 2\end{bmatrix},\quad [k]=\begin{bmatrix}4 & -1\\ -1 & 4\end{bmatrix},\quad \{x(0)\}=\begin{Bmatrix}2\\ 0\end{Bmatrix},\quad \{\dot{x}(0)\}=\begin{Bmatrix}0\\ 0\end{Bmatrix}.$$

Sample Dynamics Exam Problems, Cont.

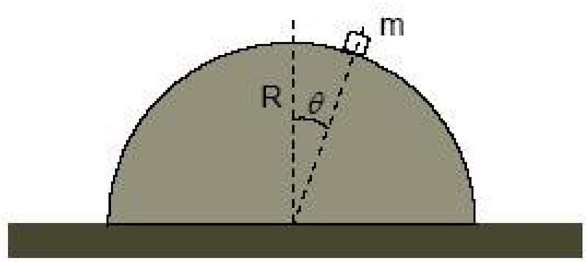
4. Derive the boundary-value problem for a circular shaft fixed at the end $x=0$ and free at the end $x=L$. Let the circular shaft be uniform and have G and ρ as the Shear modulus and mass density [mass/unit volume], respectively. Also, obtain a closed-form solution of the eigenvalue problem and plot the first three natural modes.



5. Derive the equations of motion for the system shown. The angle θ is arbitrarily large.



6. A particle of mass m slides without friction on a fixed cylinder of radius R. The particle is released from rest on the top of the cylinder. Calculate the reaction force exerted on the particle as a function of θ.



Listing of Topics for Preliminary Examination in Experimental Mechanics

Topics to be covered on the Preliminary Examination in Experimental Mechanics are taken primarily from those topics covered in the undergraduate course MAE 370 –Mechanics of Materials and in the graduate course MAE 577 – Experimental Techniques in Solid Mechanics.

1. Creation of free body diagrams for a prismatic beam followed by calculation of reactions at points of constraint, construction of shear force and bending moment diagrams, and stress analysis of the cross section to determine normal and shear stresses.

2. Creation of free body diagrams for a prismatic beam followed by calculation of reactions at points of constraint, analytical formulation of moment distribution, derivation of elastic curve, and calculation of slope and deflection at points along the span.

3. Overview of three-dimensional linear elasticity problem including how unknowns (displacements, strains, and stresses) are related to governing equations (equilibrium, strain/displacement and/or compatibility, constitutive) and calculation of principal stress/strain and maximum shear stress/strain via graphical (Mohr's Circle) or analytical (transformation equations) methods.

4. Photoelasticity including knowledge of plane and circular polariscopes and the fringes that occur (isochromatics and isoclinics); methods for calibration (tensile and bending specimens) and compensation (color, Tardy method, Babinet-Soril compensator); birefringent coatings including knowledge of reflection polariscope and calibration method; overview of 3-D photoelasticity including techniques for stress freezing, analysis, and calibration; and, calculation of stress concentration factors.

5. Brittle coatings including theory (relationship between strain/stress in specimen and coating), calibration (using end loaded cantilever beam), and application (interpretation of isostatics/isopatics).

6. Moire analysis including geometrical relationships (governing equation), strain displacement relations, in-plane displacement measurement, and shadow moire.

7. Electrical resistance strain gages including parametrical study of resistance (gage factor), transverse sensitivity, rosettes, circuitry (Wheatstone bridge), and transducer design (active/dummy gages in half/full bridge).

List of Topics for Preliminary Examination in Fluid Mechanics

Topics to be covered on the Preliminary Examination in Fluid Mechanics are taken primarily from those topics covered in the undergraduate course MAE 310 – Fluid Mechanics I and in the graduate courses: MAE 520 – Compressible Aerodynamics and MAE 651 – Viscous Fluid Mechanics.

Fluid Mechanics I (MAE 310)
Ref: F. M. White, *Fluid Mechanics,* **5th** ed., McGraw-Hill, New York, 2003

Sec 1.1-1.9
Sec 2.1-2.7
Sec 3.1-3.4, 3.7
Sec 4.1-4.3, 4.6-4.10
Sec 5.1-5.5
Sec 6.1-6.9, 6.11-6.12

Compressible Aerodynamics (MAE 520)
Ref: J. D. Anderson, *Modern Compressible Flow with Historical Perspective,* 3rd ed. McGraw-Hill, New York, 2003.

1. One-Dimensional Flow (Chap. 3)
    a. Isentropic flow
    b. Stagnation conditions
    c. Sonic conditions
    d. Normal Shocks
    e. Flow with simple heat addition (Raleigh Flow)
    f. Flow with friction (Fanno Flow)

2. Oblique shock waves (Chap. 4)
    a. β-θ Mach chart
    b. Flow over wedges and cones
    c. Shock reflections

3. Prandtl-Meyer Expansion (Chap. 4)

4. Shock-Expansion theory (Chap. 4)

5. Flow in nozzles and diffusers (Chap.5)
    a. Area-velocity relation
    b. Nozzle design conditions
    c. Nozzle off design performance

6. Crocco's Theorem (Chap. 6)

7. Unsteady flow (Chap. 7)
    a. Transformation from moving to stationary shock frame

8. Linearized Flow (Chap. 9)
    a. Prandtl-Glauert, correction
    b. Supersonic thin airfoil theory

NOTE: Compressible flow tables and charts will be provided when necessary.

Viscous Fluid Mechanics (MAE 651)

Ref: F. M. White, *Viscous Fluid Flow,* 3rd ed., McGraw-Hill, New York, 2005.

Sec 1-1 through 1-4
Sec 2-1 through 2-4; 2-6 through 2-1.1
Sec 3-1 through 3-9
Sec 4-1 through 4-6; 4-9; 4-10
Sec 6-1, 6-2

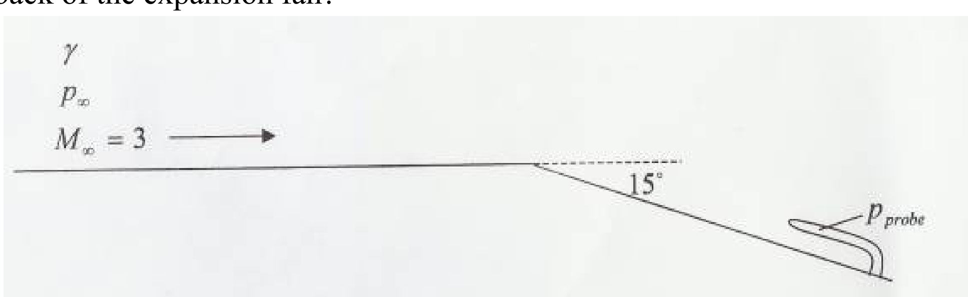
Sample Fluid Mechanics Exam Problems

1. A high-pressure air tank exhausts into a converging-diverging nozzle with a variable back pressure (P_b) at the exit.

   Sketch plots of P/Po vs. x and M vs. x for the following cases:

   a. The maximum subsonic exit Mach number with isentropic flow throughout the nozzle.
   b. Isentropic flow throughout the nozzle with $P_b = P_{design}$.
   c. Sonic flow at the throat and $P_b > P_{design}$, but P_b is less that the pressure in part
   d. (a.). Indicate where oblique shocks occur outside the nozzle. In parts (a.) – (c.) **CLEARLY** indicate the locations of the throat, exit, $P = P^*$, and $M = 1$.
   e. Plot a T-s diagram for a typical case in part (c.). **CLEARLY** indicate changes in stagnation and static properties, and the location of the throat and exit.
   f. Sketch the mass flow rate ($\dot{m}$) in the nozzle for $0 \leq P_b/Po \leq 1.0$. Indicate the general locations of the flow conditions for parts (a.) – (c.).
   g. Explain the process for determining the flow turning angle for an oblique shock at the nozzle exit. What tables and equations would you use? You can use a sketch to help explain your answer.

2. Consider the supersonic flow of air over a ramp as shown below. A Pitot probe is mounted on the ramp. The conditions **after** the turn are $M = 3.93$ and $\nu = 64.76°$.
   a. Draw any waves (shocks or expansions) in the flowfield.
   b. Determine the ratio of the Pitot pressure measured by the probe to the freestream pressure.
   c. What is the ratio of the measured Pitot pressure and the freestream total pressure?
   d. What is the Prandtl-Meyer angle for the free stream flow?
   e. Relative to the freestream, what are the angles of the Mach lines at the front and the back of the expansion fan?



3. Consider a stationary shock in a monatomic gas ($\gamma = 5/3$, $R = 2079$ J/kg-K). The stagnation temperature and density ahead of the shock are 700 K and 0.16 kg/m^3, respectively. The velocity after the shock is 892 m/s. Determine u_1 and ρ_2. **Hint:** you will need to use the Prandtl Relation to obtain a solution.

4. You have been assigned the job of designing the inlet of a low speed jet trainer. The inlet has the following properties at its entrance:
   p = 2044.8 lbf/ft^2, A = 2.65 ft^2, V = 300 ft/sec, T = 500 °R, ρ = 2.38 × 10^{-3} slugs/ft^3
   At the other end of the inlet is the engine compressor face, which requires a pressure of 1656 lbf/ft^2. Assume the flow is steady, quasi-one-dimensional, inviscid (i.e., reversible), and adiabatic. Note that for air R = 1716 ft-lbf/slug-°R.
   a. Is the flow compressible or incompressible? Why or why not?
   b. Calculate the velocity and area at the compressor face.
   c. Sketch the inlet flow process on a T-s diagram. Explicitly indicate any changes in static or stagnation properties. Indicate where the flow sonic conditions (T^*, p^*) would occur.

5. In a certain (r, θ, φ) coordinate system, a flow is such that there is symmetry in θ and the continuity equation is given by

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \rho v_r\right) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \varphi}\left(\rho v_\varphi\right) = 0$$

   Define a stream function ψ such that the continuity equation is satisfied identically.

6. Consider an incompressible turbulent flow and define

$$u = \bar{u} + u'$$
$$v = \bar{v} + v'$$
$$w = \bar{w} + w'$$

   a. Begin with the continuity equation in the form

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

   and use Reynolds averaging to prove that the mean and fluctuating velocity components each separately satisfy an equation of continuity.

   b. Reynolds average the x-momentum equation convective acceleration term defined by

$$\frac{Du}{Dt} = \frac{\partial (uu)}{\partial x} + \frac{\partial (uv)}{\partial y} + \frac{\partial (uw)}{\partial z}$$

   and explicitly identify the so-called Reynolds stresses.

Sample Fluid Mechanics Exam Problems, Cont.

7. An 8-m long umbilical cord (a small diameter tube) supplies gaseous oxygen to an astronaut. The pressure, density, and temperature at the inlet (station 1) are 250 kPa, 3.4 kg/m^3, and 283 K, respectively. The inlet is subsonic and the oxygen must be supplied at 0.06 kg/s. The tube exit pressure (station 2) must be 50 kPa. The tube has an effective friction factor, *f*, of 0.0039. Note that for oxygen $\gamma = 1.4$ and $R = 287$ J/kg-K.
   a. Describe the steps you would use to determine the diameter of the tube. Note that this is an iterative procedure. Assume you have Fanno flow tables. Specify any other equations you would use.
   b. Sketch the flow through the tube on *T-s* diagram. **CLEARLY** indicate changes in static and stagnation properties, the sonic reference conditions, and the process path.

8. An incompressible flow field is characterized by the stream function $\psi = 3X^2y - y^3$
   a. Determine whether the flow is rotational or irrotational
   b. Show that the magnitude of the velocity of any point in the flow field depends only on the distance of the point from the origin of coordinates.

9. An infinite flat plate bounds a semi-infinite incompressible fluid. Initially, the plate and the fluid are at rest. At time t=0, the plate is impulsively set into motion with constant velocity, U, moving in its own plane. Find the velocity of the fluid of any point as a function of time.

Listing of Topics for Preliminary Examination in Heat Transfer

Topics to be covered on the Preliminary Exam in Heat Transfer are taken primarily from the undergraduate course MAE 450 - Introduction to Heat and Mass Transfer and the graduate course MAE 643 – Advanced Heat and Mass Transfer. The topics on the preliminary examination from these courses focus on the fundamentals of heat transfer by conduction, convection and radiation.

1. The development *of* the "heat diffusion equation for a general unsteady conduction heat transfer.

2. Solution 2D temperature distribution for rectangular domain with constant temperature boundaries.

3. Temperature distribution on constant cross-section fin of infinite length exposed to convection.

4. Temperature history *of* small element of mass suddenly exposed to convection.

5. Convective heat transfers similarity to viscous laminar boundary layer flow.

6. Convective heat transfer between two infinite parallel plates of different temperatures when one plate is moving relative to the other plate.

7. Temperature profile for laminar flow in a circular tube having a wall temperature different from the mean temperature *of* the flowing fluid. Assume fully developed laminar viscous flow.

8. In flow over a flat plate *of* constant surface temperature, show how the convective heat transfer changes as a function of the position from the leading edge of plate.

9. For laminar fully developed flow in a circular tube, develop the relationship for the mean temperature, as a function of distance from the inlet, of the fluid when the tube surface experiences constant surface heat flux.

10. For given spectral absorptivity of a surface and a given spectral irradiation of that surface, determine the total absorptivity for the surface. What would the absorptivity of this surface be if the irradiation were solar radiation?

11. Consider a two surface enclosure with each surface having different uniform temperatures. What is the net radiative exchange between the two surfaces when both surfaces have emissivity of 1.0? What is the net radiative exchange when both surfaces are gray with emissivities between 0.0 and 1.0?

12. To illustrate the greenhouse effect, take a typical size room covered with glass surfaces. Show how the solar energy can maintain the greenhouse at acceptable temperature during both day and night when the outside temperature is below freezing.

13. For an N black surface enclosure, what is the net radiative heat transfer from each surface? 14) For a three surface gray enclosure with all surface having different uniform temperatures, what is the net radiative heat transfer from each surface when all surfaces are gray

14. Consider a sphere of given temperature and surface emissivity on an infinite plane having a different temperature and emissivity. What is the radiative heat transfer between the sphere and the infinite plane?

Sample Heat Transfer Exam Problems

1. Determine the view factor for a very small disk A_1 and a large parallel disk A_2 located a distance L directly above the smaller one. Draw a sketch with necessary labels for this problem.

2. Consider an enclosure with diffusely reflecting walls. Derive an expression for the net heat loss of the surface by radiation in terms of the surface area A_i , view factor F_{i-k} and the blackbody emissive power e_{bi} and e_{bk} . With diffusely reflecting walls, determine the net heat loss in terms of the radiosity B_i.

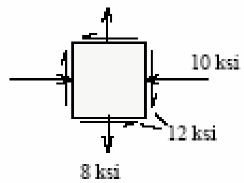
Listing of Topics for Preliminary Examination in Solid/Structural Mechanics

Topics to be covered on the Preliminary Examination in Solid/Structural Mechanics are taken primarily from those topics covered in the undergraduate course on MAE 370 - Mechanics of Materials. It helps to have completed MAE 574 - Applied Mechanics of Solids, although this is not mandatory.

1. Analysis of basic flexural, tensional, and axial members; stress and deformation determinations. Derivation of basic equations with lists of assumptions.
2. Determination of principal stresses, strains, and planes (directions)
3. Stress and stain transformations from one coordinate system to another
4. Stresses and strains relative to arbitrary planes
5. Theories of failure.
6. Energy methods for determining deflections - Castigliano theorems...
7. Analysis of static ally indeterminate trusses and beams.
8. Analysis of curved beams; stress and deformation.
9. Analysis of cylindrical and spherical thin-walled pressure vessels
10. Generalized Hooke's law.
11. Buckling analysis for columns.
12. Stress and deformation analysis under combined loads.
13. Derivation of relations between elastic material properties (E, G, K, etc.)
14. Strain rosette analysis.
15. Field equations and boundary conditions for solid mechanics problems
16. Decomposition of stress and strain tensors into deviation and dilatational components.

Sample Solid/Structural Mechanics Exam Problems

1. For the state of plane stress shown on the stress element below, determine the following:



(a) Maximum Shear Stress: ____________________

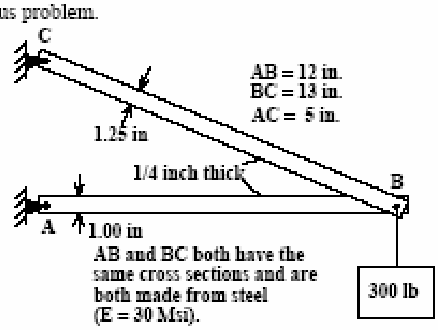
(b) Principal Stresses: ________________________

(c) Show the principal stresses on a properly oriented element

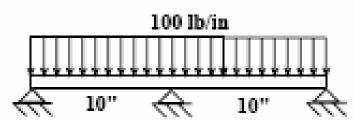
2. Determine the principal strains and their orientations in the previous problem.

3. The support shown has a weight of 300 pounds hung on the end (at B). Determine the maximum deflection in the vertical direction at B.

Δ_{max} = ____________



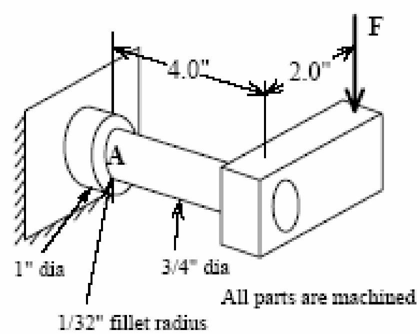
4. Determine the reactions at the supports of the shown beam (the beam is a rod with a 5/8 inch diameter and is made of steel).



5. An aluminum can is 2.4" in diameter an 0.007" thick. The can is 4.50 inches tall. If the yield strength of the aluminum is 30 ksi, determine the maximum allowable pressure in the can.

6. The bracket shown on the right is likely to fail at the cross section identified by **A**. It is desired to have a factor of safety of 2.0 in this application. Determine the maximum steady load **F** which may be applied if the bracket is made from a steel with a yield strength of 50 ksi

F_{max} = _________



A table with equations for simply supported beam slopes and deflections is provided for these problems.

Listing of Topics for Preliminary Examination in Thermodynamics

Topics to be covered on the Preliminary Examination in Thermodynamics are taken primarily from those topics covered in the undergraduate courses: MAE 342 – Thermodynamics I and II; and the graduate course MAE 641 – Advanced Thermodynamics.

1. The first law of thermodynamics: Energy principle
   - Evaluating energy transfer by work
   - Evaluating energy transfer by heat
   - Energy analysis of cycles

2. The second law of thermodynamics: Entropy concept
   - Reversible and irreversible processes
   - Entropy change in internally reversible processes
   - Entropy balance for closed systems
   - Entropy rate balance for control volumes
   - Isentropic processes and isentropic efficiencies of turbines, nozzles, etc.
   - Heat transfer and work in internally reversible, steady state flow processes

3. Control volume energy analysis
   - Steady state analysis: Closed systems
   - Transient analysis: Open systems

4. Equation of state
   - Ideal gas
   - Real gas

5. Energy (availability) analysis

6. Compressible flow through nozzles and diffusers

7. Refrigeration and heat pump systems

8. Thermodynamics relations
   - Using the equation of state
   - Developing property relations
     - Helmholtz function
     - Gibbs Function
   - p-v-T relations for gas mixtures

9. Ideal gas mixtures chrometrics

10. Reacting mixtures and combustion

11. Chemical and phase equilibrium

Sample Thermodynamics Exam Problems

1. Air at 10°C and 80 kPa enters the diffuser of a jet engine steadily with a velocity of 200 m/s. The inlet area of the diffuser is $0.4m^2$. The air leaves the diffuser with a velocity that is very small compared with the inlet velocity. Determine the mass flow rate of the air and the temperature of the air leaving the diffuser.
   Gas Constant: R = 0.287 kPa - m^3/kgK. Cp ≅ 1.003 kJ/kgK.
2. A Carnot heat engine is operating between 900 K and 300 K. If the value of entropy of the working fluid at the end of the heat input process is 100 kJ/K and the entropy at the end of the heat rejection process is 50 kJ/K, what is the work output for a cycle? Plot the cycle on a T-S diagram and show the work output on the diagram.
3. A spherical balloon contains 25 m^3 of helium gas at 20°C and 150 kPa. A valve is now opened, and the helium is allowed to escape slowly. The valve is closed when the pressure inside the balloon drops to the atmospheric pressure of 100 kPa. The elasticity of the balloon material is such that the pressure inside the balloon during the process varies with volume according to the relation P = a + bV, where a = -100 kPa and b is a constant. Disregarding any heat transfer, determine: **(a)** the final temperature in the balloon; and **(b)** the mass of helium that has escaped.
4. Steam enters an insulated turbine operating at steady state. At the entrance, the pressure is 10 bar, the temperature is 600 °C and the velocity is 50 m/s. At the exit, the pressure is 0.35 bar and the velocity is 100 m/s. The work developed per kg of steam flowing is claimed to be 1000 kJ/kg. Is the claim correct? Explain.
5. A mixture initially containing 1 mole of N_2 and 1 mole of H_2 is allowed to react and come to equilibrium at 10 atm and 800K. The equilibrium mixture consists of n_1 moles of NH_3, n_2 moles of N_2 and n_3 moles of H_2.
   a. Set up the necessary equations to solve for the n's.
   b. If the pressure is raised, will the proportion of ammonia in the equilibrium mixture increase, decrease, or remain the same?

6. Derive the following two Maxwell relations from the Gibbs function and Helmholtz function respectfully;

$$\left(\frac{\partial v}{\partial T}\right)_P = -\left(\frac{\partial s}{\partial P}\right)_T , \quad \left(\frac{\partial P}{\partial T}\right)_v = -\left(\frac{\partial s}{\partial v}\right)_T$$

7. A rigid tank contains 10 lbs of water in a two phase liquid/vapor state. Initially the temperature is 300 °F and the quality is 0.5. Heat transfer to the water occurs until the temperature is 600 °F.
   a. What is the mass of the vapor initially in the tank?
   b. What is the phase of the water after the temperature increase?
   c. What is the final pressure in the tank?

Listing of Topics for Preliminary Examination in Chemical Engineering

Topics to be covered on the Preliminary Examination in Chemical Engineering are taken primarily from those topics covered in undergraduate course CHE 344 – Chemical Engineering Thermodynamics, and the graduates courses CHE/MAE 649 - Mass Transfer Operation and CHE 658 - Catalysis and Reactor Design.

1. Multi-component Phase Equilibrium and Chemical Equilibrium systems.

2. Fugacity and activity coefficient calculations.

3. Diffusion theory and convective mass transfer analyses.

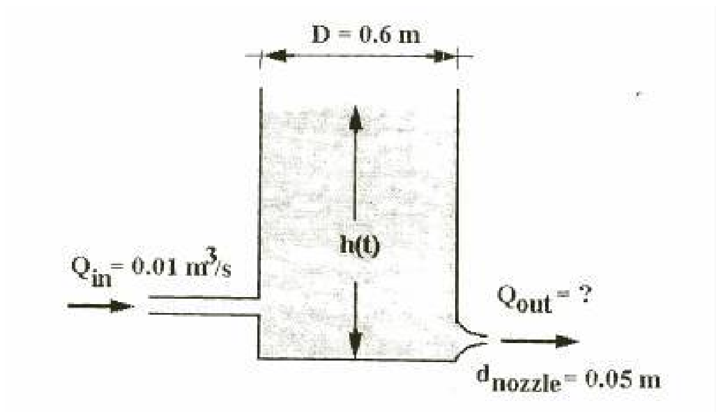
4. Mass transfer operations involve stage-wise operation (such as distillation) and rate-controlled (such as packed-bed absorption towers) operations.

5. Chemical kinetics for homogeneous and heterogeneous systems.

6. Reactor Designs principles involving parallel and series of **CSTR's** and **PFR'** s.

Sample Chemical Engineering Exam Problems

1. Water enters a cylindrical tank at a flow rate of 0.01 m^3/s. The tank is 3 m tall and has a diameter D_{tank} = 0.6 m. Also, water leaves the tank through a smoothly rounded nozzle, d_{nozzle} = 0.05 m, located at the bottom of the tank. At t = 0, the water level in the tank is h = 2.75 m.
    a. Derive an expression for h(t).
    b. What limit will h(t) approach for $t \to \infty$?



2. A liquid film wetted column is used to scrub a process gas containing 10 mole % chlorine (averaged molecular weight of the gas is about 30). The bulk gas flows at a rate of 15 kg/min. The column is 0.6 m in diameter. The thin liquid film, initially pure (free of chlorine), is a dilute aqueous sodium carbonate solution, with molecular weight 20, and is flowing at 50 kg/min. The solubility of Cl_2 in this solution can be approximated with the data supplied. Ninety percent of the chlorine is to be removed. The **overall, averaged mass transfer coefficient** is given according to:

$$K_{y,AVG} = 0.85\left[\frac{kgmole}{\min m^2 mole - fraction}\right] Re^{0.5}\, Sc^{0.1} \,,$$

   the density of the gas is 4 kg/m^3, viscosity = 2.7 E-5 kg/m-sec, diffusivity = 9 E-6 m^2/sec. The operating conditions are 1 ATM and 20°C. **Calculate height of the column.**

3. Consider a situation where there is a spill of 10 gm of liquid toluene (C_7H_8) on the ground. The spill is open to the atmosphere and the diffusion of toluene vapor may be considered to be occurring through a film 2 mm thick. A slight wind across the spill maintains zero concentration of toluene on the ambient. The conditions of the ambient are 25°C and 1 ATM. The vapor pressure at 25°C is 0.038 ATM, the diffusivity of the toluene in air that is given to you is 0.75E-5 m^2/sec. The exposed area is estimated to be 5 cm^2. It takes 20 minutes to completely evaporate the liquid. Calculate the diffusivity of vapor toluene.

Sample Chemical Engineering Exam Problems, Cont.

4. The irreversible gas-phase reaction $3A \rightarrow 2B$ is to take place in a *constant pressure* isothermal batch reactor. The reaction is *zeroeth* order overall. Determine the time required to reach 90% conversion of *A*.

   Initial Conditions: mole fraction of *A* equals 1; 400 K; 831.4 kPa; 1 liter

   Rate Data: The rate law constant at 400 K is 0.00100 moles per liter per second.

5. The elementary, reversible, liquid-phase reaction $A + 2B \longleftrightarrow 2C$ is operated in an isothermal CSTR. Find the reactor volume required to reach 90% of the equilibrium conversion for *B*.

   Inlet Stream: Equimolar in *A* and *B*; C_{Ao} = 2.0 mol per liter; ν_o = 0.5 liters per second

   Rate Data: Equilibrium constant = 4.2 liters per mole; Forward reaction rate constant equals 0.00420 liters squared per mole squared per second.

   Suggestion: Do not spend a lot of time determining an exact value of *Xeq*. Estimate *Xeq*. to its nearest tenth (e.g., 0.4, 0.5, 0.6 …).

6. Consider a non-Newtonian fluid with

$$\tau_{yx} = -\mu_o \frac{du}{dy} \pm \tau_o \quad if \left|\tau_{yx}\right| > \tau_o$$

$$\frac{du}{dy} = 0 \quad if \left|\tau_{yx}\right| < \tau_o$$

   For the fluid flowing down a vertical flat surface, derive the volumetric flow rate formula *Q* (g/sec per unit width of wall).