# College of Engineering Pune

## End Semester Examination

## Programme: F. Y. M. Tech. Mechanical Engg. (Thermal Engg.)

## Subject: Modeling of I C Engine

Time: 3.00 Hrs | Date: 11/05/2012 | Max. Marks: 50

**Instructions:** 1. Solve Any five question.
2. Illustrate your answer with neat sketches wherever necessary.
3. Assume suitable standard data, if necessary.
4. Figures to the right indicate full marks for the question.
5. Use of logarithmic tables, Mollier chart, non-programmable electronic Calculator and steam table are permitted.

Q. 1. Explain the conservation of mass, species, momentum and energy equations for the reacting flows. (10)

Q. 2. a) Calculate the expected CO mol fraction for combustion of a gasoline with x = 8, y = 17, and with the air supplied being 90 percent of that required for complete combustion. (04)

b) Write down the chemical kinetic relations, such as mass reaction rate, progress rate of reaction, reaction constants as Arrhenius equation for N number of species reacting through M number of reaction. (06)

Q. 3 a) Crevice volume of an engine equals 2% of the total clearance volume. It can be assumed that pressure in the crevices is about the same as in the combustion chamber but the temperature stays at the cylinder wall temperature of 180°C. Cylinder inlet conditions are 60°C and 98 kPa, and the compression ratio is 9.6:1, take adiabatic index as 1.35. (04)

Calculate i) What percent of thc fuel is trapped in the crevices at the end of compression stroke?

ii) What percent of the fuel ends up in the exhaust due to being trapped in the crevice volume?

b) Differentiate between the DI and IDI diesel engine and draw the proportionate heat release diagrams of them. (06)

Q 4 a) The spark plug is fired at 18°bTDC in an engine running at 1800 rpm. It takes 8° of engine rotation to start combustion and get into flame propagation mode. Flame termination occurs at 12° aTDC. Bore diameter is 8.4 cm and spark plug is offset 8 mm from the centreline of the cylinder. The flame front can be approximated as a sphere moving out from the spark plug. Calculate the effective flame front speed during flame propagation. (04)

b) Derive from engine geometry the total volume and change in volume per deg of crank angle. (06)

Q 5 a) In fuel-rich combustion product mixtures, equilibrium between the (04) species $CO_2$, $H_20$, $CO$, and $H_2$ is often assumed to determine the burned gas composition. For $\varphi = 1.2$, for $C_8H_{18}$-air combustion products, determine the mole fractions of the product species at 1700 K, the equilibrium constant for this reaction is 3.388.

b) A Four stroke engine DI diesel engine having, injection quantity = 14 $mm^3$/stroke, Spray hole diameter, $d_o$ = 0.27 mm, Bowl pressure and temperature is 45 bar, Viscosity of fuel, $\nu_f$ = 5 $mm^2$/s, density of fuel, $\rho_f$ = 840 $kg/m^3$, injection duration, $\Delta t$ = 1.8 msec, injection pressure = 400 bar, speed of engine = 1500 rpm, equivalent diameter of orifice, $d_e = d_o$, Sauter mean diameter of droplet in m is given by (06)

$$SMD = 1.58 \frac{Q^{0.21}}{\Delta p^{0.5}} \nu^{0.2} C_D^{0.39}$$

and

$$x = \sqrt{8 u_j d_e t}$$

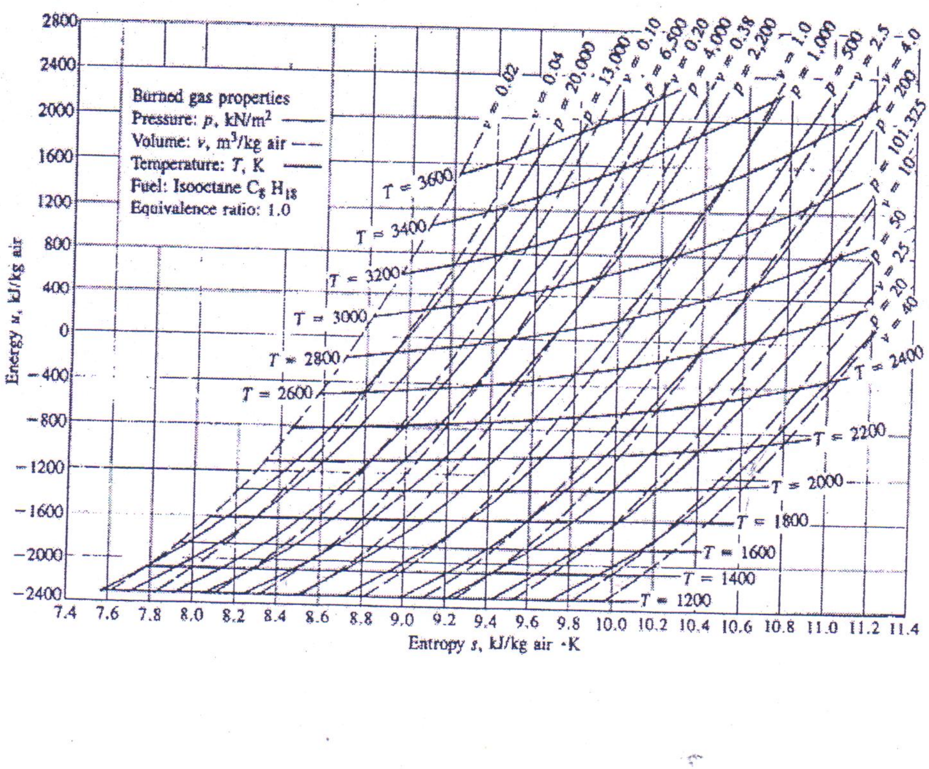
Where, Q = Rate of injection, m/s,
$\Delta p$ = Differential pressure, $N/m^2$,
$\nu$ = Kinematic viscosity, $m^2/s$,
$C_D$ = Coefficient of discharge = 0.6
$u_j$ = velocity of fuel at the orifice

Determine the SMD and explain effect of injection pressure on SMD. Also velocity of fuel, axial distance of fuel jet at time is 1ms.

Q 6 a) Explain different heat transfer models used in I C Engine modeling. (04)

b) Calculate the temperature and pressure after constant-volume adiabatic combustion and constant-pressure adiabatic combustion of the unburned mixture (with $\varphi$ = 1.0 and $x_b$ = 0.08). The state of the unburned mixture which is (06)

$T_u$ = 682 K, $p_u$ = 1.57 MPa, $v_u$ = 0.125 $m^3$/kg air, $h_{s,u}$ = 465 kJ/kg air, $u_{s,u}$ = 350 kJ/kg air, at $\varphi$ = 1.0, $\Delta h^\circ_{f,u}$ = - 129.7 - 2951 $x_b$, $\Delta u^\circ_{f,u}$ = - 118.2 - 2956 $x_b$,



# College of Engineering, Pune
## End Semester Exam – May 2012

F.Y. M.Tech. (Mechanical-Heat Power Engineering)

ME-5208: **COMPUTATIONAL FLUID DYNAMICS**

| | |
|---|---|
| Day and Date: Sunday, May 6, 2012 | Time: 9.00 to12.00 |
| Max. Marks: **50** | Duration: **Three Hours** |

**Instructions:**

1) *Answer any **five** questions.*
2) *Neat diagrams must be drawn **wherever** necessary.*
3) *Figures to the **right** indicate **full** marks.*

---

**Q.1 a)** What are various forces causing fluid flow? Derive Euler's equation of motion and show how it is converted into Beraulli's Equation considering motion of fluid element along a streamline. **[5]**

**b)** What are different types of meshing modules used in CFD? What are the selection criteria? How mesh refining is carried out? How quality of mesh is checked? **[5]**

**Q.2 a)** What is mathematical behaviour of Partial Differential Equations (PDE)? How PDE's are classified? Write simple system of quassi-linear equations with U and V as independent variables in x and y direction and using Crammer's Rule Method derive the conditions for various types of PDE's. **[6]**

**b)** Derive basic equation to solve FVM for 2D diffusion problems. **[4]**

**Q.3 a)** Explain with examples how grids are classified? What is coarse grid and fine grid? When structured and non-structured grids are used? **[4]**

**b)** Explain the analysis of errors for one dimensional unsteady state heat conduction equation: **[6]**

$$\partial T / \partial t = \alpha \partial^2 T / \partial x^2$$

and obtain the condition of stability.

**Q.4 a)** Explain the procedure of creation of Geometry on CFD software and discuss the practical aspects of computational modeling of flow domains. **[3]**

**PTO**

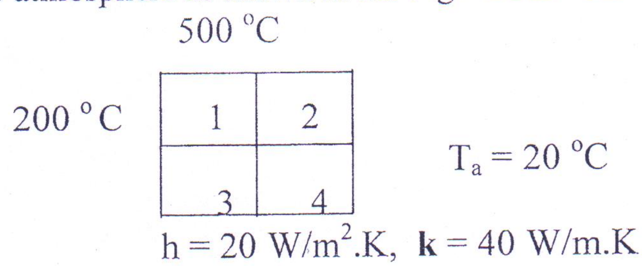
b) Derive the disctretized convection-diffusion equation using the central differencing scheme. Find the solution for property $\varphi_o=1$ at x=0 and $\varphi_L=0$ at x=L using equally spaced cells in case if velocity u=0.1 m/s and compare the results with the analytical solution [7]

$$\frac{\varphi - \varphi_o}{\Phi_L - \varphi_o} = \frac{\exp(\rho u x/\Gamma) - 1}{\exp(\rho u L/\Gamma) - 1}$$

Take L=1.0 m, $\rho = 1$ kg/m$^3$, and $\Gamma = 0.1$ kg/ms. Plot the comparative graph.

Q.5 a) Derive 3-D continuity equation in Cartesian differential form and Navier-Stokes equation and explain the terms used in them. Also write the N-S equation for Compressible flow. [5]

b) Determine temperatures at the nodes 1, 2, 3, and 4 by finite difference method. If the two sides are maintained at 500°C and 200°C and other two sides are open to atmosphere as shown in the Fig. **Take $\Delta x=\Delta y=10$ cm** [5]




Q.6 a) Consider a convective heat loss from a cylindrical fin with uniform area of cross section. The base temperature is 200°C and the end is insulated. The fin is exposed to atmospheric temperature of 30°C.Find the temperature distribution across the fin-length by using Finite Volume Method. Take Fin length = 0.4 m; m = 4; $\delta_x$ = 0.1 m. Compare the results with analytical solution and plot the comparative graph. [6]

b) Write the fundamental governing Navier-Stokes and Continuity equations for a 2-D laminar steady flow. What are the problems associated in the solutions of these equations? What is pressure velocity coupling? [4]

Q.7 Write Short Notes on **Any Three** of the following: [10]

(i) FOU, CDS, SOU and QUICK approximation in FVM,
(ii) SIMPLE algorithm,
(iii) Stability, Convergence and Accuracy,
(iv) Explicit and Implicit Approach,
(v) Conservativesness, Boundedness and Transportiveness,
(vi) Staggered Grid Approach.

*******

## College of Engineering Pune

Semester End Examination, May 2012

Class: First Year M. Tech. (Thermal)

Subject: Air conditioning System Design

Date : 14th May 2012

Duration: 3 Hrs.

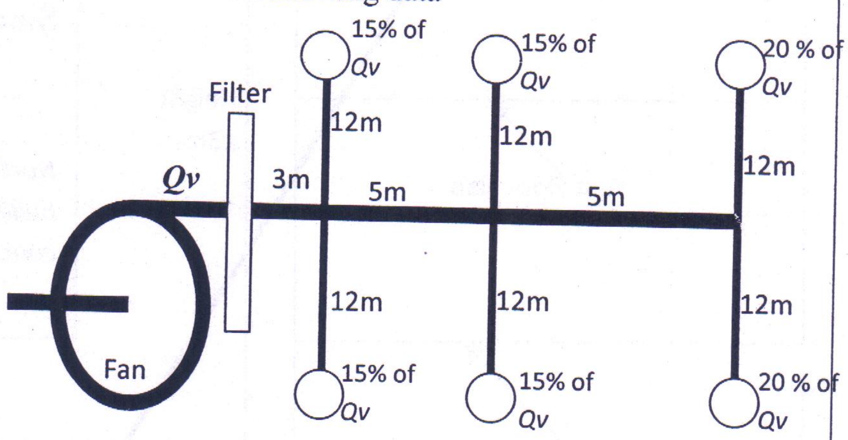
Maximum Marks: 50

1. **This is an open books and open notes examination**
2. All questions are compulsory
3. Figures to right indicate full marks
4. Make suitable assumptions if necessary and state them clearly
5. You can make use of steam tables and psychometric chart

It is required to design the air-conditioning system for a three-storied supermarket (mall). The top view and front view sketch of the super market is shown in Figure 1.

| | | | |
|---|---|---|---|
| Q.1 | A. | Outside ambient conditions are 37°C DBT and 27°C WBT. Inside design condition are 25°C DBT and 50% RH. Determine<br>i) Specific humidity and enthalpy of outside air<br>ii) Specific humidity and enthalpy of inside air | <br><br>1<br>1 |
| | B. | Consider 10 air changes per hour. 80% of air supplied to the conditioned space is re-circulated air. Determine the total CMM ($Q_v$), tempcraturc, specific humidity and enthalpy of air entering the air-conditioning apparatus. | 3 |
| | C | Determine Solar heat gain through tinted glass facades of the supermarket with following data. For calculation of solar heat gain through glass consider solar radiation intensity at 13.00hrs on 15th February at Pune from the Table1 in that case hour angle will be –15°<br>Glass thickness – 6 mm, Glass thermal conductivity – 0.78 W/m-k<br>Solar factor for tinted colour - 0.7<br>Outside glass surface heat transfer coefficient, 17.5 W/m$^2$-K<br>Inside glass surface heat transfer coefficient, 11.5 W/m$^2$-K<br>Transmissivity of glass for beam radiation – 0.8<br>Absorptivity of glass for beam radiation - 0.08<br>Transmissivity of glass for diffuse radiation -0.79 | 5 |

| | | | |
|---|---|---|---|
| | | Absorptivity of glass for diffuse radiation – 0.06 | |
| | D | Determine building solar heat gain through sidewalls using empirical method of time lag and decrement factor with following data. Take decrement factor of 0.5 and time lag as 5 hours. Neglect the area of doors.<br><br>Wall comprises of outside paint, outside concrete plaster, brickwork, inside plaster and inside paint<br><br>Building wall density – 1600kg/m$^3$<br><br>Outside wall surface heat transfer coefficient, 35 W/m$^2$-K<br><br>Inside wall surface heat transfer coefficient, 8.5 W/m$^2$-K<br><br>Thermal conductivity of paint – 0.7 W/m-k<br><br>Film thickness of outside paint – 500 microns<br><br>Thermal conductivity of concrete plaster – 8.56 W/m-k<br><br>Thickness of concrete plaster – 5 mm<br><br>Thermal conductivity of bricks – 0.77 W/m-k<br><br>Thickness of bricks, forming wall – 152.4 mm<br><br>Thickness of inside concrete plaster – 5 mm<br><br>Film thickness of inside paint – 500 microns<br><br>Absorptivity of wall surface – 0.7 | 5 |
| | E | Determine building solar heat gain through ground, ground floor slab, first floor slab and second floor slab using empirical method of time lag and decrement factor with following data. Take decrement factor of 0.6 and time lag as 5 hours.<br><br>Absorptivity of ground and all slabs – 0.75<br><br>Thickness all Slabs – 15 cm<br><br>Thermal conductivity of slab concrete – 1.73 W/m-k<br><br>Heat transfer coefficient of ground and first floor slabs for their top and bottom faces - 8 W/m$^2$-K<br><br>Outside surface heat transfer coefficient for the second floor slab, 30 W/m$^2$-K<br><br>Temperature of top and bottom faces of the ground floor slab, first floor slab and ground floor – 26.5°C.<br><br>Over all heat transfer coefficient for the floor – 6 W/m$^2$-K | 5 |
| Q2. | A | Determine occupancy heat gain, equipment heat gain and heat gain due to infiltrated air through door openings with following data | 4 |

| | | | |
|---|---|---|---|
| | | Number of Occupants in the super market at any time – 300<br>Sensible heat gain – 75 W/ person<br>Latent heat gain: 85 W/person<br>Lighting in the super market – 40 W CFL Lamps: 120 Nos.<br>200 W Incandescent lamps: 45 Nos.<br>Fans – 75 W rating, Efficiency 80%, 150 Nos.<br>No. of lifts – 3 Lift motor rating 10 kW, Efficiency 85%,<br>Sensible heat gain of other Appliances: 9 kW<br>Latent heat gain of other kitchen equipment: 5 kW<br>Rate of air infiltration through the doors openings – 250 CMM | |
| | B | Determine Room Sensible heat, Room latent Heat, Room Total Heat, Effective Room Sensible heat, Effective Room Latent Heat and Effective Room Total Heat | 4 |
| | C | Determine supply air condition, apparatus dew point and bye pass factor Estimate capacity of the refrigeration plant in TR | 4 |
| | D | Optimise the diameter of the main duct as well as branch ducts as per the lay out shown below and with following data<br><br><br>Duct Material: Aluminium, Density 2700 kg/m$^3$, Cost Rs. 230 per kg<br>Duct thickness: 1.5 mm<br>Friction Factor for duct Surface: 0.0195<br>Multiplying factor for all branch takeoffs and filters – 0.4 and 0.5 respectively<br>Multiplying factor for all reduction/ enlargements in duct sections – 0.2<br>Outlet velocities of air at all points – 200 mpm<br>Hours of operation of the duct fan: 4200 hours per year | 8 |

| | | | |
|---|---|---|---|
| | | Electricity rate: Rs. 8 per kWh<br>Capital cost of the fan: 10000 Rs. per kW | |
| Q3. | A | Write short notes on<br>i) Design of Cooling and dehumidifying coils<br>ii) Freeze protection in cooling coils | 10 |

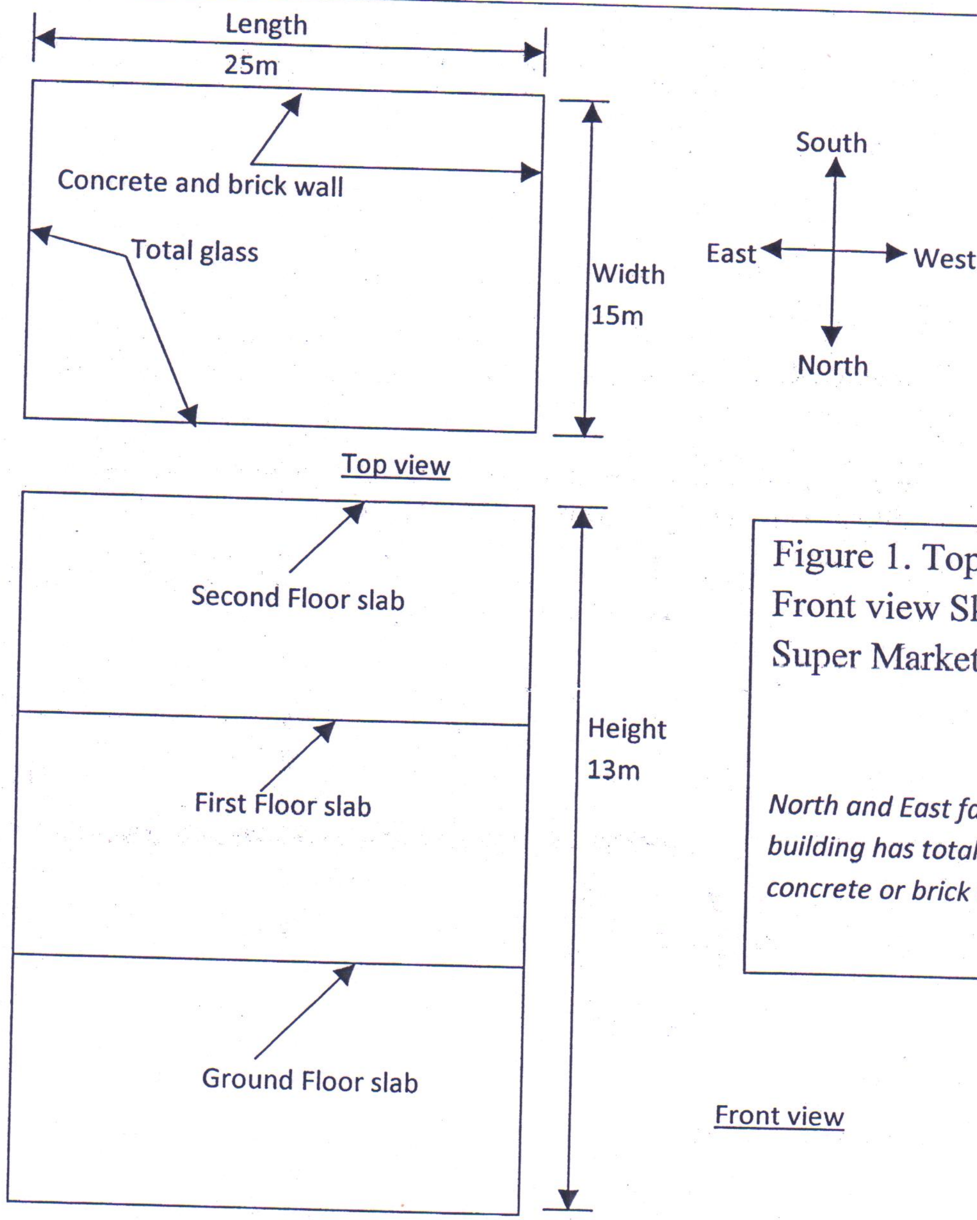



Figure 1. Top View and Front view Sketch of the Super Market

*North and East faces of the building has total glass and no concrete or brick wall*

**Table 1.Solar Radiation and ambient temperature data for Pune on 15th February**

| Solar Time | Global radiation, kW/m$^2$ | Diffuse Radiation, kW/m$^2$ | Ambient temperature, °C | Sol Air temperature for walls | Sol Air temperature for Roof |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 18.6 | | |
| 2 | 0 | 0 | 17.6 | | |
| 3 | 0 | 0 | 16.7 | | |
| 4 | 0 | 0 | 15.8 | | |
| 5 | 0 | 0 | 15.2 | | |
| 6 | 0.001 | 0 | 14.5 | | |
| 7 | 0.04 | 0.024 | 14 | | |
| 8 | 0.23 | 0.075 | 14.3 | | |
| 9 | 0.464 | 0.103 | 19.6 | | |
| 10 | 0.67 | 0.12 | 23.8 | | |
| 11 | 0.812 | 0.127 | 27 | | |
| 12 | 0.883 | 0.132 | 29.3 | | |
| 13 | 0.883 | 0.136 | 30.9 | | |
| 14 | 0.807 | 0.137 | 31.9 | | |
| 15 | 0.662 | 0.126 | 32.5 | | |
| 16 | 0.463 | 0.109 | 32.5 | | |
| 17 | 0.231 | 0.075 | 31.9 | | |
| 18 | 0.042 | 0.023 | 30.3 | | |
| 19 | 0 | 0 | 28.8 | | |
| 20 | 0 | 0 | 25.8 | | |
| 21 | 0 | 0 | 24.2 | | |
| 22 | 0 | 0 | 22.6 | | |
| 23 | 0 | 0 | 21.1 | | |
| 24 | 0 | 0 | 19.9 | | |

# College of Engineering, Pune – 411 005.

## End SEM Examination

## (AT/DE - 516) Mechanics of Composite Materials

Program : M. Tech.
Course : Mechanical Engg.
Year : 2011 – 12

Date: $6^{th}$ May 2012
Max. Marks : 50
Duration: 3 hour

.............................................................................................................................

**Instructions: -** 1) Solve **all** questions. Use following lamina properties wherever required.
3) Draw neat figures wherever required.

$E_1$= 38 GPa, $E_2$= 8 GPa, $G_{12}$ = 4 GPa and $v$ = 0.2, ply thickness ($t_k$) = 0.1 mm

$\alpha_1 = 7e10^{-6}\ /^0C, \alpha_2 = 21e10^{-6}\ /^0C, \beta_1 = 0, \beta_2 = 0.2$

$F_{1T}$ = 1100 MPa, $F_{1C}$ = 600 MPa, $F_{2T}$ = 30 MPa, $F_{2C}$ = 145 MPa, $F_6$ = 85 MPa

.............................................................................................................................

**Q1. Solve any five. Each question carries six marks.**

a) What are the advantages and disadvantages of thermoset and thermoplastic composites processing?

b) Write procedure steps using flowchart for finding out stress-strain plot for laminate subjected to uniaxial load. Symbols can be used instead of text.

c) What is safety factor? How it can be used in design and analysis of composite materials?

d) Calculate $\bar{\alpha}_x$ and $\bar{\alpha}_y$ for $[0/90]_S$.

e) A $[0/90]_S$ laminate consist of unidirectional plies and is subjected to a tensile force Nx = 200 N/mm. Check whether failure will occur according to maximum stress theory. Find minimum safety factor for First-ply failure.

f) Find the in-plane and flexural stiffness constants for a $[0/\pm 45]_S$ laminate.

g) Find the difference between the vertical deflection (through the thickness) at the center and the four corners of a [0/90] graphite/epoxy cuboid laminate. The top surface dimensions of the laminate are 60 cm – 20 cm. The laminate is subjected to a temperature change of –75 °C.

h) Calculate the residual stresses at the bottom surface of the 90° ply and 0° ply in a two ply [0/90] laminate subjected to a temperature change of –75°C.

P.T.O

**Q2. Solve any five. Each question carries four marks.**

I) Find the following for a 60° angle lamina: 1. Coefficients of thermal expansion, 2. Coefficients of moisture expansion, and 3. Strains under a temperature change of –100 °C and a moisture absorption of 0.02 kg/kg.

II) A [±45] laminate was cooled down from 200 $^0$C to 50 $^0$C during curing and deformation measured are as follows $\varepsilon_x^0 = \varepsilon_y^0 = -7.5*10^{-6}$, $\varepsilon_{xy}^0 = 0, k_x = k_y = 0, k_{xy} = 2$ /m. Compute the lamina residual stresses.

III) What is total-ply failure method and partial-ply failure method for analysis of last-ply failure or ultimate failure of laminate?

IV) Show that for a regular anti-symmetric laminate Axs = Ays = Dxs = Dys = 0.

V) What are types of failures in laminated composite materials? How properties can be modified after damage in failed layer?

VI) What are merits and demerits of adhesive bonded joints?

VII) Describe the four major steps typically taken in the making of composite products?

VIII) Why do thermoplastics have shorter processing times than thermosets? And Why it is easier to process with thermosets than with thermoplastics?

IX) Write down the composite manufacturing techniques that use prepregs?

------ * * * * ------

# College of Engineering Pune

## Department of Mechanical Engineering

## Endsem Exam, Fracture Mechanics

Max. marks: 100 | Duration: 3 Hrs

May 8, 2012 | Four formula sheets allowed (no exchange allowed)

- *It is a good practice to carry out cancelling of the units.*
- *Present the results with units.*
- *Carry out the calculations with four significant digits only.*

| | | |
|---|---|---|
| Q1 | a). Does an overload pulse retard the crack growth of subsequent pulses?<br><br>b). A critical machine component was detected to have a sharp edge crack of 4 mm length. The plate was much larger than the crack size. The machine would be exposed to a corrosive medium for 100 hours and then will be subjected to a fatigue load of frequency 2 cycles per second. Determine the life of the component in hours for the following properties:<br><br>Corrosion: $\frac{da}{dt} = 8 \times 10^{-6}$ mm/s ; $\sigma$= 110 MPa√m<br><br>Fatigue: $\frac{da}{dN} = 6.8 \times 10^{-12} \Delta K^3$ ; $\sigma^{max} = 110$ MPa√m ; $\sigma^{min} = 0.0$ MPa√m<br><br>$K_{Ic}$=60 MPa√m | 3<br><br>+15<br><br>=18 |
| Q2 | a). Does the strain energy of a component increase with crack growth? Justify your answer.<br><br>b). Consider a large plate of a center crack subjected to mixed mode loading. The plate is loaded in *plane stress* to have<br><br>$K_I = 90\ MPa\sqrt{m}, \quad K_{II} = 30\ MPa\sqrt{m}$<br><br>The yield stress of the material is 300 MPa. Determine the extent of plastic zone on $x_2$-axis ($\theta$=90$^0$). Use Tresca Criterion for the approximate analysis; that is, do not use any correction for the existence of plastic zone | 3<br><br>+13<br><br>=16 |
| Q3 | a). While estimating $K_I$ of a through the thickness crack in a plate using a small strain gage why do we bond the strain gage at some finite value of polar coordinate θ and at and inclined with respect to $x_1$-axis? Do not make use of any equation in your reply.<br><br>b). Why do we carry out do multiple loading and unloading cycles while finding interlaminar $G_{Ic}$ of a composite laminate? | 3<br><br>+3 |

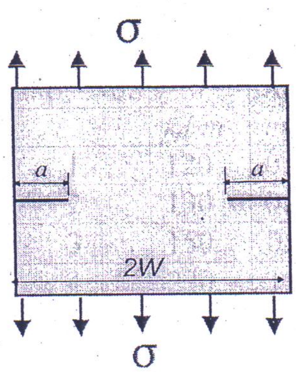
| | | |
|---|---|---|
| | c). Why do we have a code on maximum SIF of fatigue load that is applied to sharpen a crack for $K_{Ic}$-Test? | +3 |
| | d). For experimental determination of $J_{Ic}$, five identical SENB specimens were employed of an unknown material with following properties and the dimensions of the specimen:<br><br>$\sigma_{ys}$=300 MPa, $\sigma_{uts}$=430 MPa, Thickness B= 18 mm, Width W=36 mm, Span S=144 mm; $a \approx 18$ *mm*<br><br>J was found out for different crack growth as shown in the table below: | +7<br><br>=16 |

| Expt. No. | *J* | $\Delta a$ |
|---|---|---|
| | $kJ/m^2$ | *mm* |
| 1 | 120 | 0.2 |
| 2 | 130 | 0.3 |
| 3 | 150 | 0.5 |
| 4 | 220 | 1.0 |
| 5 | 260 | 1.2 |

Graph paper on p4

**Q4** Consider a double-edge-cracked plate as shown in the figure below. For this case $f(\alpha)$ varies between *0.982* and *1.05* when $\alpha$ $(=a/W)$ is varied between *0.1* and *0.7*. Since the variation is small, we take its value to be equal to unity. For this material **16**

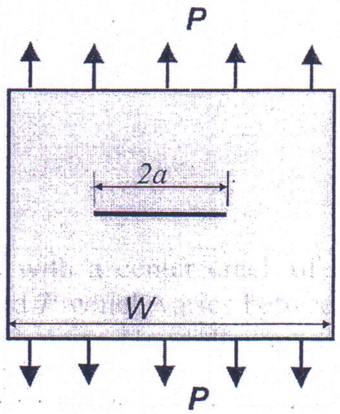
$K_{Ic}=80\ MPa\sqrt{m}$ and $\sigma_{ys}=825\ MPa.$




Draw a graph showing maximum safe load (far field stress) the plate can carry against fracture failure. Also, on the same graph draw the curve which shows safe stress (far field stress) against yielding of un-cracked ligament. Now, show the safe region in which the plate will not fail either against fracture or against yielding of un-cracked ligament.

Graph paper on p4

**Q5** A plate of width $W=40$ *mm* with a center crack of length of $2a$ is subjected to a constant amplitude tensile load $P$ which varies between *80,000 N* and *40,000 N*. The thickness of the plate is *10 mm*. The following data were obtained from the experiment; Crack with initial length $2a = 3$ mm grows *to 3.2 mm* in *10,000* cycles. With the same load the crack keeps on growing. When the crack was *20 mm* long, it took *1000* cycles to grow to 22 mm. Determine the constants of Paris Law. For solving this problem. $F(a/W)$ can be taken as $\left[\sec\left(\frac{\pi a}{W}\right)\right]^{1/2}$, where $a$ and $W$ are defined in the figure below. **18**



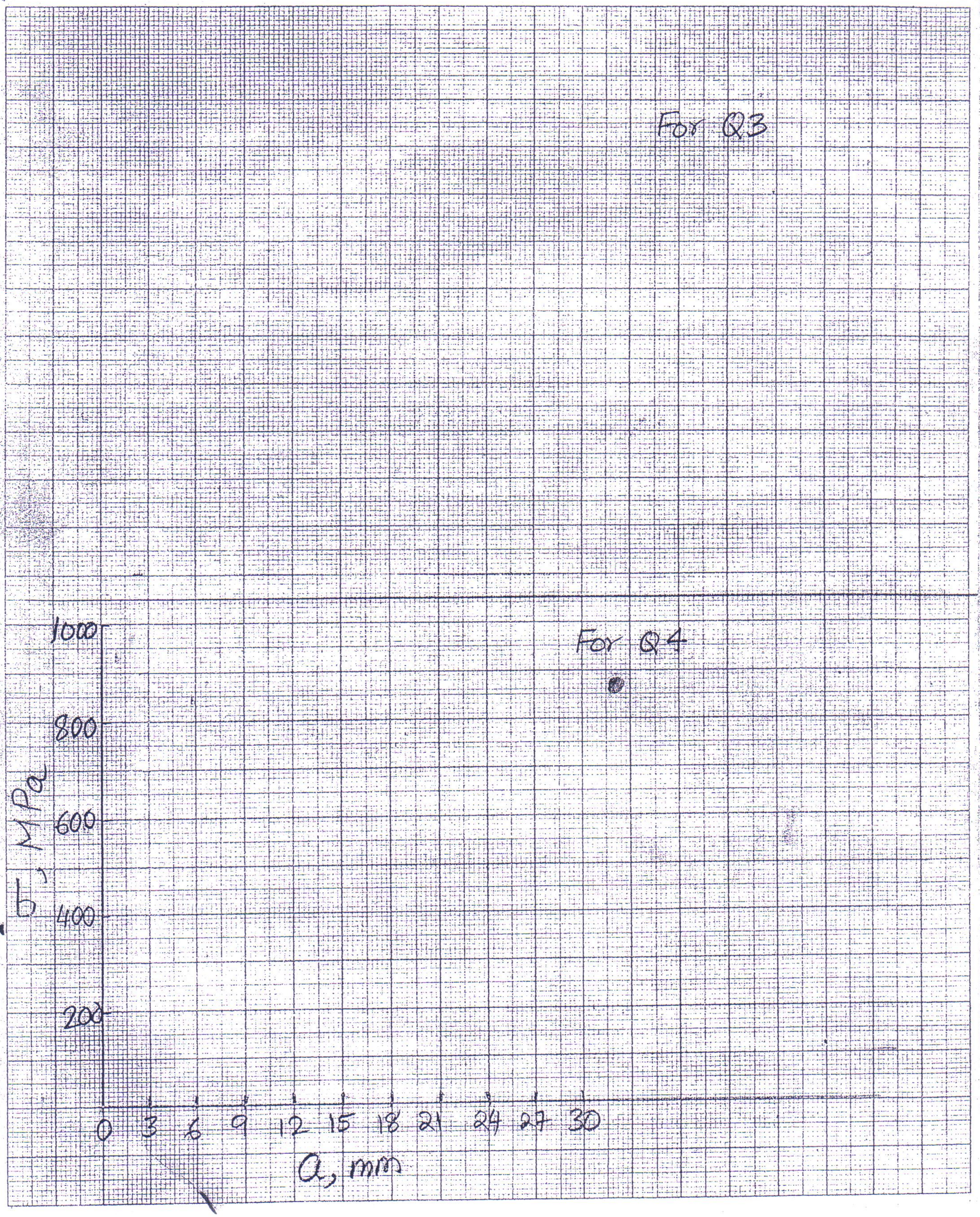

**Q6** a). Why do we pass a bunch of high frequency wave pulses through the component in which we try to detect cracks through ultrasonic testing? **4**

b). An axis of a vehicle is being tested by hammering the one end of the axle. The axle is 2 m long a crack is located at a distance of 0.7 m from the end on which hammer impacts. Find out the frequencies generated. The wave velocity is 5 mm/μs. **+4**

c). Describe the working concept of Dye Penetration test. **+4**

d). Explain the Modified Griffith Criterion for mixed mode cases. **+4 =16**

Graph papers for Q3 and Q4. Detach this sheet from the question paper and attach it with answer copy. Make sure that you attach it somewhere inside the copy and not as the last page.



# COLLEGE OF ENGINEERING PUNE
## End Semester Exam 2011-2012 (II SEM)
## Mechanics of Composite Materials (IS502-1)

Programme: M. Tech. | Date: 04-05-2012
Duration: 180 minutes | Max. Marks: 50
Time: 09-00 am to 12-00 noon

*Instructions* :

1) **Answer all questions.**
2) **Figures to the right indicate full marks.**
3) **Use of non-programmable calculator is allowed.**
4) **Assume suitable data if required.**

Q.1 Answer the following: (12)

1. State the assumptions of Classical laminate theory and write the expressions for the displacement field approximation. Also obtain the expressions for strains from the displacement field approximation.
2. Which elements of ABD matrix should be nonzero to cause the following:
   i. Extension – Shear coupling
   ii. Bending – Twist coupling
   iii. Extension – Twist and Bending – Shear coupling
   iv. In plane – Out of plane coupling

Q.2 Explain the following failure theories: (08)

i. Tsai-Wu failure theory
ii. Maximum stress failure theory

Q.3 Consider a four-layer $[0/90]_S$ graphite-reinforced polymer composite laminate with the elastic constants as given below: (10)

$E_1 = 181000$ MPa, $E_2 = E_3 = 10300$ MPa

$\nu_{23} = 0.33$ $\nu_{12} = \nu_{13} = 0.28$

$G_{23} = 2870$ MPa, $G_{12} = G_{13} = 7170$ MPa

The laminate has a total thickness of 2 mm. The four layers are of equal thickness. Obtain the effective elastic constants for the laminate.

Q.4 Consider a four-layer $[0/30]_S$ graphite-reinforced polymer composite laminate with the elastic constants as given in [Q.3]. The four layers are of equal thickness and total thickness of the laminate is 4 mm. Nxx = 100 N/mm and Mxx = 5000 N mm/mm. (15)

Determine,

i. the three components of stress at the interface locations,

ii. the three components of stress at mid plane of each layer

Q.5 Determine which laminas of the laminate of [Q. 4], will fail. Use the maximum stress failure theory. Assume following: (05)

$\sigma_T^1 = 1500$ MPa $\qquad \sigma_C^1 = 1500$ MPa

$\sigma_T^2 = 40$ MPa $\qquad \sigma_C^2 = 246$ MPa

$\tau^F{}_{12} = 68$ MPa

---