Semester I

Discipline: MECHANICAL ENGINEERING

Stream: ME3

CODE	COMPUTATIONAL METHODS FOR ENGINEERS	CATEGORY	L	T	P	CREDIT
221TME100		Discipline Core	3	0	0	3

Preamble:

Numerical simulations are the most reliable tool of mechanical engineers to solve the problems in the domain and advanced computational methods are a critical component of that. This course targets to introduce the advanced numerical techniques required to solve the mechanical engineering problems.

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Solve system of equations using numerical techniques
CO 2	Apply numerical schemes to integrate, differentiate and curve fit
CO 3	Determine solutions of ODE and PDE using computational methods
CO 4	Formulate a Mechanical Engineering problem and solve that using computer based numerical procedure and submit micro-project
CO 5	Apply two different numerical methods to solve (manual/computer) a problem and compare the merits and demerits of those schemes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**
CO 1			3	2	3	2
CO 2			3	2	3	2
CO 3			3	2	3	2
CO 4	3	2		2	3	2
CO 5	2	2		2	3	2

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	20%
Analyse	60%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 40 Marks

Micro project/Course based project : 20 marks

(Formulate a mechanical engineering problem and solve that using computer based numerical procedure and submit as project. The project shall be done individually. Group projects not permitted.)
Course based task (programming)/Seminar/Quiz: 10 marks Test

paper, 1 No. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 60 Marks

The end semester examination will be conducted by the University for Core Courses. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

QP Code: **Total Pages:**

Reg No.:_________ **Name:___________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year
Discipline: Mechanical Engineering
Course Code:
Course Name: Computational Methods for Engineers

Max. Marks: 60 **Duration: 2.5 Hours**

PART A

	Answer all questions, each carries 5 marks.	**Marks**
1	Use Gauss elimination to solve $3x_1 - 0.1x_2 - 0.2x_3 = 7.85$ $0.1x_1 + 7x_2 - 0.3x_3 = -19.3$ $0.3x_1 - 0.2x_2 + 10x_3 = 71.4$	**(5)**
2	Explain the procedure of Newton-Raphson method and draw a flowchart.	**(5)**
3	Explain the Trapezoidal rule and derive the equation for the same.	**(5)**
4	Use the classical fourth-order RK method to integrate $f(x, y) = -2x^3 + 12x^2 - 20x + 8.5$ using a step size of $h = 0.5$ and an initial condition of $y = 1$ at $x = 0$.	**(5)**
5	Write a short note on any simple implicit method.	**(5)**

PART B

Answer any 5 full questions, each question carries 7 marks.

6	Use Newton- Raphson method to determine a root of the equation $f(x) = x^3-13x-12$	**(7)**

7 Given these data, **(7)**

x	1.6	2	2.5	3.2	4	4.5
f(x)	2	8	14	15	8	2

Calculate f(2.8) using Newton's interpolating polynomials of order 1 through 3. Choose the sequence of the points for your estimates to attain the best possible accuracy.

8 Evaluate the following integral: **(7)**

$$\int_0^{\pi/2} (6 + 3\cos x)\, dx$$

(a) single application of Simpson's 1/3 rule

(b) multiple-application Simpson's 1/3 rule, with n = 4.

9 Solve the following initial value problem over the interval from t = 0 to 2 where y(0) = 1. Display all your results on the same graph. **(7)**

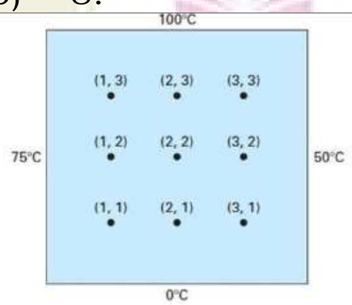
$$\frac{dy}{dt} = yt^2 - 1.1y$$

(a) Euler's method with h = 0.5 and 0.25.

(b) Fourth-order RK method with h = 0.5.

10 Use the shooting method to solve $7\, d^2y/dx^2 - 2\, dy/dx - y + x = 0$ with the boundary conditions y(0) = 5 and y(20) = 8. **(7)**

11 **(7)**



Use Liebmann's method (Gauss-Seidel) to solve for the temperature of the heated plate in figure. Employ overrelaxation with a value of 1.5 for the weighting factor and iterate to es $\varepsilon_s = 1\%$.

12	Use the simple implicit method to solve for the temperature distribution of a long, thin rod with a length of 10 cm and the following values: k’ = 0.49 cal/(s . cm . ºC), Δx = 2 cm, and Δt = 0.1 s. At t =- 0, the temperature of the rod is zero and the boundary conditions are fixed for all times at T(0) = 100ºC and T(10) = 50ºC. Note that the rod is aluminium with C = 0.2174 cal/(g . ºC) and ρ = 2.7 g/cm^3 . Therefore, k = 0.49/ (2.7 . 0.2174) 5 0.835 cm^2 /s and λ = 0.835(0.1)/(2)^2 = 0.020875.	**(7)**

Syllabus

Module 1

Introduction to Computational methods, system of equations-Revision - Formulation of engineering problems and solution using computational methods; significant figures, accuracy, precision, round off error, truncation error,Taylor series expansion of a polynomial. Roots of equation - Bisection, Newton-Raphson, and Bairstow methods. Linear algebraic equations - Gauss Elimination method, LU decomposition. Non-linear equation- Gauss-Jordan method, Newton- Raphson for simultaneous equations. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 2

Curve fitting- Linear regression- linearization of non linear relation, linear least squares, multiple linear regression. Non linear regression- polynomial regression, Gauss- Newton method. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 3

Numerical differentiation and integration- Derivatives- Newton's forward, backward, divided difference and Sterling formula. Integration -Trapezoidal rule, Simpsons one third, Simpsons three eighth, Gauss quadrature-two & three point. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 4

Numerical solutions to ordinary differential equations- Taylors method, Eulers method, Runge-Kutta method fourth order, simultaneous first order, Milne's predictor corrector. Initial value problem - shooting method, Eigen values - polynomial method, power method. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 5

Solution of partial differential equation & Interpolation-

Interpolation - Newtons forward and backward, divided difference linear & quadratic, Lagrange interpolation, cubic splines, Hermites interpolation. Solution of partial differential equation - Difference equations, Elliptic equation- Laplace equation, Poisson equation, Liebmann's iterative methods, Parabolic equation- Bender-Schmidt method, simple implicit, Crank-Nicolson scheme, Solution of hyperbolic equation. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Course Plan

No	Topic	No. of Lectures - 40 Hrs
1	**Introduction to Computational methods, system of equations**	
1.1	Revision - Formulation of engineering problems and solution using computational methods; significant figures, accuracy, precision, round off error, truncation error, Taylor series expansion of a polynomial	2
1.2	Roots of equation - Bisection, Newton Raphson, and Bairstow methods	2
1.3	Linear algebraic equations - Gauss Elimination method, LU decomposition. Non-linear equation- Gauss-Jordan method, Newton- Raphson for simultaneous equations	3
1.4	Case studies with computer programs (Python/Scilab/ C++/Fortran/other) (Not for End Semester Examination)	2
2	**Curve fitting**	
2.1	Linear regression- linearization of non linear relation, linear least squares, multiple linear regression	2
2.2	Non linear regression- polynomial regression, Gauss- Newton method	3
2.3	Case studies with computer programs (Python/Scilab/C++/Fortran/other) (Not for End Semester Examination)	2

3	**Numerical differentiation and integration**	
3.1	Derivatives - Newton's forward, backward, divided difference and Sterling formula	3
3.2	Integration -Trapezoidal rule, Simpsons one third, Simpsons three eighth, Gauss quadrature-two & three point.	3
3.3	Case studies with computer programs (Python/Scilab/ C++/Fortran/other) (Not for End Semester Examination)	2
4	**Numerical solutions to ordinary differential equations**	
4.1	Taylors method, Eulers method, Runge-Kutta method fourth order, simultaneous first order, Milne's predictor corrector	3
4.2	Initial value problem - shooting method, Eigen values -polynomial method, power method	3
4.3	Case studies with computer programs (Python/Scilab/C++/Fortran/other)(Not for End Semester Examination)	2
5	**Solution of partial differential equation & Interpolation**	
5.1	Interpolation - Newtons forward and backward, divided difference linear & quadratic, Lagrange interpolation, cubic splines, Hermites interpolation	3
5.2	Solution of partial differential equation - Difference equations, Elliptic equation- Laplace equation, Poisson equation, Liebmann's iterative methods, Parabolic equation- Bender-Schmidt method, simple implicit, Crank-Nicolson scheme, Solution of hyperbolic equation	3

5.3	Case studies with computer programs (Python/Scilab/ C++/Fortran/other)(Not for End Semester Examination)	2

Reference Books

1. Steven C. Chapra, Raymond P Canale, Numerical Methods for Engineering, 8e, Mc-Graw Hill Education (2020)
2. B.S. Grewal, numerical methods in engineering science with programs in C, C++ and MATLAB(10th edition) Khanna Publisher (2020)
3. E Balaguruswamy, Numerical Methods, McGraw Hill (2017)
4. P. Kandasamy , K. Thilagavathy and K. Gunavathy., Numerical Methods, S Chand & Co Ltd (2016)
5. S. P. Venkateshan, Prasanna Swaminathan, Computational Methods in Engineering, Ane Books (2014)
6. VN Vedamurthy & SN Iyengar, Numerical Methods, S Chand & Co Ltd (2014)
7. AK Jaiswal and Anju Khandelwal, Computer Based Numerical and Statistical Techniques, New Age International (2009)
8. Gilbert Strang, Computational Science and Engineering, Wellesley-Cambridge Press (2007)
9. Joe D Hoffman, Numerical Methods for Engineers and Scientists, Second Edition, Marcel Dekker (2001)

CODE	ADVANCED HEAT TRANSFER	CATEGORY	L	T	P	CREDIT
221TME005		PROGRAM CORE	3	0	0	3

Preamble: Make the students to model heat transfer problems by integrating heat transfer physics with mathematical tools

Pre-requisites: Basic knowledge in Heat Transfer

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Develop mathematical model of heat transfer problems
CO 2	Justify the equations developed for heat transfer problems
CO 3	Summarize condensation and boiling heat transfer
CO 4	Explain laws of heat transfer

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3		3		
CO 2	3		3		
CO 3	2		3		
CO 4			3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40 %
Analyse	30 %
Evaluate	20 %
Create	10 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: **60 marks**

The end semester examination will be conducted by the University. There will be two parts; **Part A and Part B**. **Part A** will contain **5** numerical/short answer questions with 1 question from each module, having **5 marks for each question** (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. **Part B** will contain **7** questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. **Each question can carry 7 marks**.

Model Question paper

Reg. No:___________

Name:______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M. TECH DEGREE EXAMINATION, MONTH & YEAR

FIRST SEMESTER

ADVANCED HEAT TRANSFER

Time: 2.5 hrs Marks: 60

Part A (5 x 5 = 25 Marks)

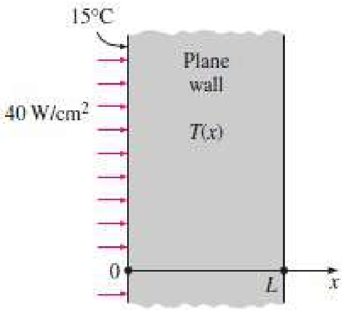
Answer all questions. Each question carries 5 marks

1. Consider a steam pipe of length L = 20 m, inner radius R_1 = 8 cm, outer radius R_2 = 10 cm, and thermal conductivity k = 20 W/mK. The inner and outer surfaces of the pipe are maintained at average temperatures of T_1 = 160°C and T_2 = 70°C, respectively. Obtain a general relation for the temperature distribution inside the pipe under steady conditions, and determine the rate of heat loss from the steam through the pipe.
2. Hot water is to be cooled as it flows through the tubes exposed to atmospheric air. Fins are to be attached in order to enhance heat transfer. Would you recommend attaching the fins inside or outside the tubes? Why?
3. Explain Reynold's –Colburn analogy.
4. Draw the boiling curve and identify the different boiling regimes. Also, explain the characteristics of each regime.
5. What is a graybody? How does it differ from a blackbody? What is a diffuse gray surface?

Part B (5 x 7 = 35 Marks)

Answer any five questions. Each question carries 7 marks

6. Consider steady one-dimensional heat conduction in a large plane wall of thickness L and constant thermal conductivity k with no heat generation. Obtain an expression for the variation of temperature within the wall for the following boundary conditions



7. The temperature of a gas stream is to be measured by a thermocouple whose junction can be approximated as 1.2 mm-diameter sphere. The properties of the junction are *thermal conductivity* = 35 W/mK, *density* = 8500 kg/m^3, and *specific heat* = 320 J/kgK, and the heat transfer coefficient between the junction and the gas is 65 W/m^{2}K. Determine how long it will take for the thermocouple to read 99 percent of the initial temperature difference.
8. Using integral method, obtain an expression for Nusselt number when a liquid metal flows over a flat plate assuming the flow is to be laminar.
9. Water is to be heated from 15°C to 65°C as it flows through a 3-cm-internal diameter 5-m-long tube. The tube is equipped with an electric resistance heater that provides uniform heating throughout the surface of the tube. The outer surface of the heater is well insulated, so that in steady operation all the heat generated in the heater is transferred to the water in the tube. If the system is to provide hot water at a rate of 10 L/min, determine the power rating of the resistance heater. Also, estimate the inner surface temperature of the pipe at the exit.
10. Write down the continuity, momentum and energy equation for a natural convection boundary layer on a vertical heated plate. Non-dimensionalise the governing equations and identify the non-dimensional numbers. Explain the significance of each dimensionless numbers.
11. The condenser of a steam power plant operates at a pressure of 7.38 kPa. Steam at this pressure condenses on the outer surfaces of

horizontal pipes through which cooling water circulates. The outer diameter of the pipes is 3 cm, and the outer surfaces of the pipes are maintained at 30°C. Determine (*a*) the rate of heat transfer to the cooling water circulating in the pipes and (*b*) the rate of condensation of steam per unit length of a horizontal pipe.

12 Two parallel plates of size 0.5m by 1m spaced 0.5m apart are located in a very large room, the walls of which are maintained at a temperature of 27°C. One pate is maintained at a temperature of 1000°C and the other at 500°C. Their emissivities are 0.2 and 0.5 respectively. If the plates exchange heat between themselves and surroundings, find the net heat transfer to each plate and to the room. Consider only the plate surfaces facing each other.

Syllabus

Module 1

Introduction to Heat transfer. Thermodynamics and heat transfer, Modes of heat transfer, Fourier's law and thermal conductivity, Differential equation of heat conduction, boundary conditions and initial conditions.

Module 2

Solution to heat conduction problems, Conduction with thermal energy generation, Heat transfer from extended surfaces, fin efficiency and effectiveness, Transient conduction, Lumped capacitance model One dimensional transient problems, analytical solutions, Unsteady conduction from a semi-infinite solid.

Module 3

Convection. Governing equation for convection, use of energy integral equation, liquid metal heat transfer over a flat plate, 2D laminar couette flow and non-dimensional numbers, flow over flat plate (laminar, transition and turbulent heat transfer), heat transfer in high- speed flow, concept of adiabatic wall temperature. Pipe flow – concept of developed temperature profile, Laminar flow heat transfer in circular pipe –constant heat flux and constant wall temperature, thermal entrance region, Reynold's –Colburn analogy, turbulent flow heat transfer in circular pipe.

Module 4

Natural convection, boiling and condensation. Natural convection-Governing equation, Vertical plate and horizontal cylinder, horizontal plate, enclosed spaces, combined natural and forced convection. Heat transfer during boiling, boiling of saturated liquid, Nucleation boiling, Maximum heat flux, Film boiling. Heat transfer during condensation, Film condensation, Condensation for horizontal tube, Condensation on a vertical tube.

Module 5

Radiation Heat transfer. Concept of black body, black body radiation, Planck's law, Stefan Boltzman law, Wien's Displacement law, Kirchhoff's law. Radiosity Irradiation method, Parallel plates, Radiation shield. Radiation exchange between black surfaces, shape factor, Radiation exchange between gray surfaces.

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Heat transfer**	
1.1	Thermodynamics and heat transfer, Modes of heat transfer	1
1.2	Fourier's law and thermal conductivity	2
1.3	Differential equation of heat conduction, boundary conditions and initial conditions	3
2	**Solution to heat conduction problems**	
2.1	Conduction with thermal energy generation	3
2.2	Heat transfer from extended surfaces, fin efficiency and effectiveness	3
2.3	Transient conduction, Lumped capacitance model One dimensional transient problems, analytical solutions	2
2.4	Unsteady conduction from a semi-infinite solid.	2
3	Convection.	
3.1	Governing equation for convection, use of energy integral equation, liquid metal heat transfer over a flat plate	3
3.2	2D laminar couette flow and non-dimensional numbers, flow over flat plate (laminar, transition and turbulent heat transfer), heat transfer in high- speed flow, concept of adiabatic wall temperature.	3
3.3	Pipe flow – concept of developed temperature profile, Laminar flow heat transfer in circular pipe –constant heat flux and constant wall temperature, thermal entrance region	2
3.4	Reynold's –Colburn analogy, turbulent flow heat transfer in circular pipe	2
4	Natural convection, boiling and condensation	
4.1	Natural convection-Governing equation, Vertical plate and horizontal cylinder, horizontal plate, enclosed spaces,	2

	combined natural and forced convection	
4.2	Heat transfer during boiling, boiling of saturated liquid, Nucleation boiling, Maximum heat flux, Film boiling	2
4.3	Heat transfer during condensation, Film condensation, Condensation for horizontal tube, Condensation on a vertical tube	3
5	Radiation Heat transfer	
5.1	Concept of black body, black body radiation, Planck's law, Stefan Boltzman law, Wien's Displacement law, Kirchhoff's law.	3
5.2	Radiosity Irradiation method, Parallel plates, Radiation shield.	2
5.3	Radiation exchange between black surfaces, shape factor, Radiation exchange between gray surfaces	2

Reference Books

1. Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, Adrienne S. Lavine, Principles of Heat and Mass Transfer, 8^{th} Edition, 2017
2. Mayers, G.E., Analytical methods in Conduction Heat Transfer, McGraw Hill, 1971.
3. Kays, W.M. and Crawford, M.E., Convective Heat and Mass Transfer, McGraw Hill Int. Edition, 3rd edition, 1993.
4. Siegel, R. and Howell, J.R, Thermal Radiation Heat Transfer, Taylor and Francis, 2002.
5. Yunus, A. Cengel, Heat Transfer –A Practical Approach, Second Edition ,Tata Mc Graw Hill, 2010

CODE 221TME006	COMPRESSIBLE AND INCOMPRESSIBLE FLUIDS	CATEGORY	L	T	P	CREDIT
		PROGRAM CORE	3	0	0	3

Preamble: Study about various fluid flows and their properties.

Pre-requisites: Fluid Mechanics, Thermodynamics

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop conservation equations of fluid mechanic
CO 2	Determine the exact solution of laminar and turbulent flow problems
CO 3	Justify isentropic flow conditions of compressible flow
CO 4	Summarize the knowledge on Fanno, Reyleigh flow and normal and oblique shock

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1			3	2		
CO 2	3			2		
CO 3			3	1		
CO 4			3	1		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40 %
Analyse	40 %
Evaluate	20 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: **60 marks**

The end semester examination will be conducted by the University. There will be two parts; **Part A and Part B**. **Part A** will contain **5** numerical/short answer questions with 1 question from each module, having **5 marks for each question** (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. **Part B** will contain **7** questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. **Each question can carry 7 marks**.

Model Question paper

Reg. No:______________

Name:________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M. TECH DEGREE EXAMINATION, MONTH & YEAR

FIRST SEMESTER

COMPRESSIBLE AND INCOMPRESSIBLE FLUIDS

Time: 2.5 hrs

Marks: 60

Part A (5 x 5 = 25 Marks)

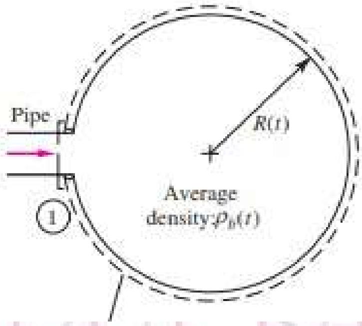
Answer all questions. Each question carries 5 marks

1. What is Stoke's hypothesis?
2. Consider two-dimensional incompressible plane viscous flow between parallel plates finite distance apart. Assume that the plates are very wide and very long, so that the flow is essentially axial. Write the simplified continuity equation.
3. Explain Prandtl boundary layer equations.
4. The Mach number and pressure at the entry if a subsonic diffuser is 0.9 and 4.165 bar. Determine the area ratio required and the pressure rise if the Mach number at the exit of the diffuser is 0.20. Assume isentropic diffusion of air.
5. How stagnation temperature will change in a compressible flow through a constant area duct with heating, if initially flow is subsonic?

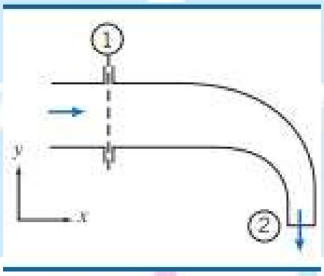
Part B (5 x 7 = 35 Marks)

Answer any five questions. Each question carries 7 marks

6. A balloon is being filled through section 1, where the area is A_1, velocity is V_1, and fluid density is ρ_1. The average density within the balloon is $\rho_{b(t)}$. Find an expression for the rate of change of system mass within the balloon at this instant.



7. Water flows steadily through the 90^0 reducing elbow shown in the diagram. At the inlet to the elbow, the absolute pressure is 220 kPa and the cross-sectional area is 0.01 m^2. At the outlet, the cross-sectional area is 0.0025 m^2 and the velocity is 16 m/s. The elbow discharges to the atmosphere. Determine the force required to hold the elbow in place.



8. Consider two-dimensional incompressible plane ($\partial/\partial z$=0) viscous flow between parallel plates a distance 2h apart. We assume that the plates are very wide and very long, so that the flow is essentially axial. The upper plate moves at velocity **V** but there is no pressure gradient. Neglect gravity effects. Develop an equation for velocity distribution in the channel.
9. For the velocity profile in laminar boundary layer

$$\frac{u}{U} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

Find the thickness of the boundary layer and the shear stress 1.5 m from the leading edge of a plate. The plate is 2m long and 1.4m wide and is placed in water which is moving with a velocity of 0.2 m/s. Find the total drag force on the plate if μ for water = 8.9 x 10-4 N.s/m^2.

10. Explain Prandtl's mixing length hypothesis.

11. Air flows steadily through a duct from 350 kPa, 60 0 C and 183 m/s at an initial state to Mach number 1.3 at the outlet, where local isentropic stagnation conditions are known to be 385 kPa and 350 K. Compute the local stagnation pressure and temperature at the duct inlet and static pressure and temperature at the duct outlet.

12. Air at p1=3 bar, T1= 288K and M1=1.5 is brought to sonic velocity in a frictionless constant area duct through which heat transfer can occur. Determine the final pressure and temperature and heat added during the process. What will be the Mach number, pressure and temperature of air if this heat is extracted from the air?

Syllabus

Module 1

Concept of a fluid, Fluid as a Continuum, Newtonian and Non-Newtonian fluids, Variation of viscosity with temperature, Eulerian and Lagrangian formulations, Reynolds transport theorem, Continuity equation, Momentum equation, Energy equation, Integral relations for a control volume, Differential relations for fluid flow, Navier Stokes equation.

Module 2

Exact solution of incompressible Navier-Stokes equations, Couette flow, fully developed flow through ducts; flow between rotating cylinders, Stokes problems, Plane Poiseuille flow: velocity distribution, maximum velocity, volume flow rate, average velocity, shear stress distribution, maximum shear stress, pressure drops in terms of average velocity.

Module 3

Boundary layer equations, Turbulence models and flow equations. Turbulent boundary layers. Prandtl's boundary layer equations, Blasius solution and other similarity solutions of the laminar boundary layer. Time averaged turbulent flow equations, Reynolds stresses, eddy viscosity, mixing length hypothesis, similarity hypothesis, flow through pipes and ducts.

Module 4

Introduction to compressible flows: basic concepts, subsonic and supersonic flows, Isentropic flow with variable area: Stagnation and Critical conditions, Mass flow rate, Isentropic flow through Convergent nozzle and Convergent Divergent nozzle.

Module 5

Fanno flow: Adiabatic flow in constant area duct with friction, Fanno line, Variation of Mach number with duct length. Rayleigh flow: Frictionless flow in constant area duct with heat transfer, Raleigh line, Thermal chocking and its consequences, Normal Shocks: Fundamental relations, Prandtl Meyer relation for normal shock, Impossibility of shock in subsonic flow. Oblique Shocks.

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Concept of a fluid, Fluid as a Continuum, Variation of viscosity with temperature.	1
1.2	Eulerian and Lagrangian formulations	1
1.3	Reynolds transport theorem, Continuity equation, Momentum equation, Energy equation,	3
1.4	Integral relations for a control volume, Differential relations for fluid flow, Navier Stokes equation.	3
2	**Module 2**	
2.1	Exact solution of the Navier-Stokes equations	2
2.2	Couette flow, fully developed flow through ducts; flow between rotating cylinders, Stokes problems	3
2.3	Plane Poiseuille flow: velocity distribution, maximum velocity, volume flow rate, average velocity, shear stress distribution, maximum shear stress, pressure drops in terms of average velocity	3
3	**Module 3**	
3.1	Boundary layer equations, Turbulence models and flow equations.	2
3.2	Turbulent boundary layers. Prandtl's boundary layer equations	2
3.3	Blasius solution and other similarity solutions of the laminar boundary layer.	2
3.4	Time averaged turbulent flow equations, Reynolds stresses, eddy viscosity, mixing length hypothesis, similarity hypothesis, flow through pipes and ducts.	2
4	**Module 4**	
4.1	Introduction to compressible flows, Basic concepts, subsonic and supersonic flows	2
4.2	Isentropic flow with variable area: Stagnation and Critical conditions	2
4.3	Mass flow rate, Isentropic flow through Convergent nozzle and Convergent Divergent nozzle	3
5	**Module 5**	
5.1	Fanno flow: Adiabatic flow in constant area duct with	3

	friction, Fanno line, Variation of Mach number with duct length.	
5.2	Rayleigh flow: Frictionless flow in constant area duct with heat transfer, Raleigh line, Thermal chocking and its consequences	3
5.3	Normal Shocks: Fundamental relations, Prandtl Meyer relation for normal shock, Impossibility of shock in subsonic flow. Oblique Shocks.	3

Reference Books

1. Som and Biswas “Advanced Fluid Mechanics”, Tata McGraw Hill.
2. Frank M White, “Fluid Mechanics”, Tata Mc Graw Hill Publishing Company Ltd., 2008.
3. Schlichting H,"Boundary Layer Theory", McGraw Hill Book Company, NewYork, 1979.
4. Shapiro A. H., "The Dynamics and Thermodynamics of Compressible Flow", Ronald Press Company, New York, 1953.
5. John D Anderson, “Modern Compressible flow”, Mc Graw Hill, 2003.
6. James John & Theo Keith, Gas Dynamics, Pearson Education, 2006.

PROGRAM ELECTIVE I

221EME024	ADVANCED THERMODYNAMICS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: Study of Thermodynamic Properties and its Advancements

Course Outcomes:

After the completion of the course the student will be able to

CO 1	The student will be able to analyse various thermodynamic systems.
CO 2	The student will be able to optimise processes using exergy methods
CO 3	The student will be able to find properties of single and multi-component systems
CO 4	The student will be able to conduct a feasible combustion analysis
CO 5	The student will be able to analyse and model combustion

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1			3		3		
CO 2					3		
CO 3		2		3			
CO 4				3			
CO 5			3				

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	50%
Analyse	25%
Evaluate	20%
Create	5%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

Reg. No:______________

Name:________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M. TECH DEGREE EXAMINATION, MONTH & YEAR FIRST SEMESTER

ADVANCED THERMODYNAMICS

Time: 2.5 hrs. **Max. Marks: 60**

PART A (5x5 = 25 Marks)

1. Does the enthalpy of formation of a substance change with temperature? What is Enthalpy of formation how does it differ from Enthalpy of combustion?
2. What is Adiabatic Combustion Temperature? If a fuel is completely burned first with the stoichiometric amount of air and then with the stoichiometric amount of pure oxygen. For which case the adiabatic flame temperature be higher?
3. A dealer advertises that he has just received a shipment of electric resistance heaters for residential buildings that have an efficiency of 100 percent. Assuming an indoor temperature of 21°C and outdoor temperature of 10°C, determine the second law efficiency of these heaters.
4. What is the importance of the van’t Hoff equation along with explanation on concept.
5. What are the molecular structures for the following: n- butane, 2,2,4-trimethyl pentane(iso-octane), diolefin(1,5-heptadiene)

PART B (5 x 7 = 35 Marks)
(Answer any fivequestions, Each question carries 7 marks)

6. Explain the following with respect to coal: (i) Proximate analysis, (ii) Ultimate analysis (iii) Higher and lower calorific value (iv) Cocking and non-cocking properties.

7. A sample of dry anthracite has the following composition by mass. C 90%; H 3%; O 2.5%; N 1%; S 0.5%; ash 3% Calculate: the stoichiometric A/F ratio; What are the advantages of gaseous fuels over solid and liquid fuels
8. What do you understand by the structure of a premixed flame? Enumerate the nature of concentration and temperature profiles in preheat and reaction zones of a flame
9. What is the importance of laminar burning velocity in flame research? How is it defined?
10. List the various means to control the HC, CO, and NOx concentration in the exhaust froman automobile. What are the effects of control means on the exhaust pollutants?
11. What are the different types of gas burners? What are they used? Briefly describe their working principles.
12. Discuss the differences in the properties of the various types of coal. Why are bituminous and anthracite coals are preferred?

Syllabus

Module I

The First Law, Terminology, Closed Systems, Work Transfer, Heat Transfer, Energy Change,Open Systems, The Second Law Closed Systems, Open Systems, Local Equilibrium. Entropy Maximum and Energy Minimum, Carathéodory's Two Axioms.

Module II 8

Availability and Exergy, Irreversibility, Graphical Representation of Available Energy and Irreversibility. Availability Balance for a Closed System. Availability Balance for an Open System, Exergy.

Module III

Uses of the Thermodynamic Relationships: Maxwells Relations for Single Component System, Clausius –Clapeyron equation, State Equations (Ideal Gas Law, Law of Corresponding States). Mixtures of Ideal Gases: Gibbs–Dalton Law, Mixture Relationships, Specific Heats of Mixtures, Entropy of Mixtures, Developing tables of Thermodynamic properties from Experimental Data.

Module IV

Combustion: Theoretical & Excess Air. Stoichiometric Air Fuel Ratio (A/F), Air Fuel Ratio from Analysis of Products. Heat of Formation and Heat of Reaction, Gibbs Energy, Chemical Potential.

Module V

Statistical Thermodynamics. Quantization of Energy, The Entropy Function, Entropy and the most Probable state. Microscopic Implications of work and heat, Entropy changes in term of macroscopic variables, the Statistical interpretation of second and third laws of thermodynamics. Elements of non-equilibrium thermodynamics: Thermodynamic Forces and Thermodynamic Velocities

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	
1.1	The First Law, Terminology, Closed Systems, Work Transfer, Heat Transfer, Energy Change,	3
1.2	Open Systems, The Second Law Closed Systems, Open Systems, Local Equilibrium.	3
1.3	Entropy Maximum and Energy Minimum, Carathéodory's Two Axioms	2
2	**Module 2**	
2.1	Availability and Exergy	1
2.2	Irreversibility, Graphical Representation of Available Energy and Irreversibility	3
2.3	Availability Balance for a Closed System	2
2.4	Availability Balance for an Open System, Exergy.	2
3	**Module 3**	
3.1	Uses of the Thermodynamic Relationships: Maxwells Relations for Single Component System,	2
3.2	Clausius –Clapeyron equation, State Equations (Ideal Gas Law, Law of Corresponding States)	2
3.3	Mixtures of Ideal Gases: Gibbs–Dalton Law, Mixture Relationships, Specific Heats of Mixtures, Entropy of Mixtures,	2
3.4	Developing tables of Thermodynamic properties from Experimental Data.	2
4	**Module 4**	
4.1	Combustion: Theoretical & Excess Air	2
4.2	Stoichiometric Air Fuel Ratio (A/F	2
4.3	Air Fuel Ratio from Analysis of Products	2
4.4	Heat of Formation and Heat of Reaction, Gibbs Energy, Chemical Potential.	2

5	**Module 5**	
5.1	Statistical Thermodynamics	1
5.2	Quantization of Energy, The Entropy Function, Entropy and the most Probable state	2
5.3	Microscopic Implications of work and heat, Entropy changes in term of macroscopic variables, the Statistical interpretation of second and third laws of thermodynamics.	3
5.4	Elements of non-equilibrium thermodynamics: Thermodynamic Forces and Thermodynamic Velocities	2

REFERENCES:

1. Advanced Thermodynamics for Engineers, Desmond E. Winterbone& Ali Turan
2. Advanced Engineering Thermodynamics, Adrian Bejan
3. Principles of Combustion, Kenneth K Kuo
4. Applied Thermodynamics for Engineering Technologists, T D Eastop&Mcconkey
5. Heat and Thermodynamics, Mark W. Zemansky& Richard H. Dittman

CODE 221EME025	RENEWABLE ENERGY SYSTEMS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: This course aims the students to know the renewable energy scenario in India, their reserves, potentials, applications and environmental aspects. The renewable energies included are solar, wind, biomass, tidal, geothermal, ocean, hydrogen energy and the fuel cells. This course enables the students to select the proper renewable energy system based on its performance and potential along with safety and environmental aspects.

After the completion of the course the student will be able to

CO 1	Identify various renewable energy sources and conversion technologies along with environmental aspects of energy utilization
CO 2	identify suitable solar thermal or solar PV technology for power generation, heating and cooling, desalinization or other applications at a given location
CO 3	Examine wind, tidal and geothermal energy conversion systems, its performance and potential along with safety and environmental aspects
CO 4	Analyze various methods and technologies of utilizing biomass as a fuel with lesser environmental impact
CO 5	Examine the hydrogen energy and fuel cells, its performance and potential along with safety and environmental aspects.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			2	3	2		
CO 2			2	3	2		
CO 3			3	2	2		
CO 4			2	2	2		
CO 5			3	2	2		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	50 %
Analyze	30 %
Evaluate	15 %
Create	5 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: **60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; **Part A and Part B**. **Part A** will contain **5** numerical/short answer questions with 1 question from each module, having **5 marks for each question** (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. **Part B** will contain **7** questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. **Each question can carry 7 marks**.

Model Question paper

Reg. No:_____________

Name:_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M. TECH DEGREE EXAMINATION, MONTH & YEAR

FIRST SEMESTER

RENEWABLE ENERGY SYSTEMS

Time: 2.5 hrs

Marks: 60

Part A (5 x 5 = 25 Marks)

Answer all questions. Each question carries 5 marks

1. Explain the benefits of renewable energy over conventional fossil fuel
2. Comment on the superior thermal efficiency of evacuated tube collectors over normal FPC.
3. What do you mean by biomass conversion? What are different types of conversions?
4. With the help of a T-S diagram explain vapour dominated geothermal system.
5. State whether SOFCs are suitable for short distance automotive (car) applications. Give reasons if your answer is yes. Otherwise, suggest a suitable type of fuel cell for such applications.

Part B (5 x 7 = 35 Marks)

Answer any five questions. Each question carries 7 marks

6. Write in detail about the Renewable energy scenario of India with specialfocus on the solar, wind and biomass energy.
7. Explain in detail about any two solar desalination techniques which use

flashing.

8. With a neat sketch explain the principle and working of a solar pond. Explain how the different layers with different concentration are maintained.
9. Derive betz limit for a horizontal axis wind turbine.
10. A 2m wave has a 6s period and occurs at surface of water 100m deep. Find the wave length, wave velocity, horizontal and vertical semi-axes for water motion at the surface. Also find the energy and power density. Density of water is 1025 kg/m^3.
11. Differentiate between torrefaction, pyrolysis and gasification. Based on what criteria will you decide which method to choose among these three for biomass conversion.
12. What are the major losses associated with the operation of a fuel cell? Discuss its I-V characteristics.

Syllabus

MODULE 1 (8 hours)

World energy use – Reserves of energy resources – Environmental aspects of energy utilization– Renewable energy scenario & policies in India – Potentials – Achievements – Applications.

MODULE 2 (8 hours)

Solar energy: Solar thermal - Flat plate and concentrating collectors – Solar heating and cooling techniques –Solar desalination – Solar Pond – Solar cooker - Solar thermal power plant – Solar photo voltaic conversion – Solar cells – PV applications.

MODULE 3 (8 hours)

Energy from biomass: Direct combustion – Pyrolysis - Biomass gasifiers – Biomethanation – Anerobic digesters - Fermentation – Ethanol production – Bio diesel – Cogeneration – Biomass applications for power generation.

MODULE 4 (8 hours)

Wind energy: Basics – Wind energy data and energy estimation – Types of wind energy systems – Performance of wind turbine generators – Safety and environmental aspects.

Ocean energy: Resources & routes - OTEC - Tidal energy – Wave energy.

Geothermal energy: Origin – Types of geothermal energy sites – Geothermal power plants

MODULE 5 (8 hours)

Introduction to hydrogen energy: Production processes – Storage and transport – Applications.

Fuel Cells: Working principle – Basic thermodynamic and electrochemical principles – Classifications – Applications for power generation-Renewable energy integrated FC systems.

No	Topic	No. of Lectures
1	**Module 1**	**8**
1.1	World energy use	1
1.2	Reserves of energy resources	1
1.3	Environmental aspects of energy utilization	2
1.4	Renewable energy scenario & policies in India	2
1.5	Potentials – Achievements – Applications	2
2	**Module 2**	**8**
2.1	Solar energy	1
2.2	Solar thermal - Flat plate and concentrating collectors	1
2.3	Solar heating and cooling techniques –Solar desalination – Solar Pond	3
2.4	Solar cooker - Solar thermal power plant – Solar photo voltaic conversion – Solar cells – PV applications	3
3	**Module 3**	**8**
3.1	Energy from biomass: Direct combustion	2
3.2	Pyrolysis - Biomass gasifiers – Bio methanation	2
3.3	Anerobic digesters - Fermentation – Ethanol production	2
3.4	Bio diesel – Cogeneration – Biomass applications for power generation	2
4	**Module 4**	**8**
4.1	Wind energy: Basics, Wind energy data and energy estimation	2
4.2	Types of wind energy systems – Performance of wind turbine generators – Safety and environmental aspects.	2
4.3	Ocean energy: Resources & routes - OTEC - Tidal energy – Wave energy.	2
4.4	Geothermal energy: Origin – Types of geothermal energy sites – Geothermal power plants	2
5	**Module 5**	**8**
5.1	Introduction to hydrogen energy: Production processes	2
5.2	Storage and transport, Applications.	2
5.3	Fuel Cells: Working principle, Basic thermodynamic and electrochemical principles	2
5.4	Classifications, Applications for power generation, Renewable energy integrated FC systems	2

Textbooks/References:

1. Renewable energy, Power for a sustainable future, Godfrey Boyle, Oxford Universitypress U.K
2. Renewable energy sources, Twidell J W & Weir A,EFN spon Ltd U.K
3. Renewable Conversion Technology, N.K.Bansal, M.Kleeman&M.Mielee, Tata Mc Graw Hill, New Delhi.
4. Solar Energy, S.P Sukhatme, Tata McGraw Hill Publishing company Ltd, New Delhi
5. Biomass Gasification, Pyrolysis and Torrefaction: Practical Design and Theory, Prabir Basu, Academic Press (2013), Second edition, ISBN: 978-0-12-396488-5
6. Understanding Clean Energy & Fuels from Biomass. H.S. Mukunda, Wiley India Pvt. Ltd, First edition, 2011, ISBN: 9788126529698
7. Wind energy conversion system, L.L.Freris, Prentice Hall U K
8. Fuel cell handbook, Seventh edition, EG&G Technical Services, Inc.
9. Alternative Transportation Fuels: Utilization in CombustionEngines, Babu M.K.G., Subramanian K.A, CRC Press (2013).

CODE 221EME026	MEASUREMENT METHODS IN THERMAL AND ENERGY SYSTEMS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 1	3	0	0	3

Preamble: Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	To provide knowledge on advance measurement techniques and to understand the various steps involved in error analysis and uncertainty analysis.
CO 2	To get an idea of the advanced measuring instruments
CO 3	To select the sensors and instruments according to the need
CO 4	To suggest modern measurement techniques in measurements
CO 5	To develop a knowledge in Analog to Digital and Digital to Analog conversion of measured values

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	1		3				
CO 2			3				
CO 3			3				
CO 4			3				
CO 5	3		3				
CO 6			3				

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%
Analyse	30%
Evaluate	20%
Create	10%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

Reg. No:_____________

Name:_______________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M. TECH DEGREE EXAMINATION, MONTH & YEAR FIRST SEMESTER

MEASUREMENT SYSTEMS IN THERMAL ENGINEERING

Time: 2.5 hrs. **Max. Marks: 60**

PART A (5 x 5 = 25 Marks)

(Answer all questions, Each question carries 5 marks)

1. What is measurement? Mention the uses of gauges, micrometers and dial gauge indicators in measurement system
2. Explain the working of Carbon pile pressure transducer
3. Discuss the working of Pirani gauge with suitable sketches
4. Discuss the principle of turbine flow meter
5. Why are digital display units more preferred by researchers in measurement?

PART B (5 x 7 = 35 Marks)

(Answer any five questions, Each question carries 7 marks)

6. Discuss the principle of any two-pressure sensing instrument
7. Explain the working of strain gauge pressure sensor instrument
8. With neat sketches explain the working of Bridgman gauge and Mcleod
 gauge in measurement
9. Explain the working of Flat Top and Natural top type of A/D convertors
10. With neat sketch explain Particle Image Velocimetry technique. Mention its advantages and disadvantages

11. Explain the working of five gas analyzer and the working of a smoke meter. Mention its advantages and disadvantages
12. With neat sketch explain Schlieren interferometer and shadowgraph. Mention its advantages and disadvantages

Syllabus

Module I

Measurement characteristics, Measurement and Instrument Classifications. Characteristics of Instruments – Static and dynamic Measurements. Errors in Measurements, Systematic and Random errors, Uncertainty, Selection of measuring instruments. Reliability of Measuring instruments

Module II

Measurement of Pressure, Various Pressure sensing elements. Bellows Inductance, Resistance types, Capacitive Pressure Transducers, Piezoelectric and Potentiometric Pressure Transducers, Strain gauge pressure sensors. Bridgeman Gauge for Very High-Pressure Measurement. Vacuum Measurement and McLeod gauge for very Low-Pressure Measurement. Pirani Gauge. Calibration Process, Dead weight Tester

Module III

Measurement of Temperature, Thermometers, Thermometers Thermocouple. Resistance Temperature Detector (RTD), Thermistor, Bi-metallic Thermometers. Thermo-electric Pyrometers, Total radiation Pyrometers. Optical Pyrometers Pressure Thermometers, Infrared Thermometers, Temperature Calibration RTD and Thermocouple calibration.

Module IV

Advance Measurement Techniques- Shadowgraph, Schlieren imaging, Interferometer, Laser Doppler Anemometer, Particle Image Velocimetry Hot Wire Anemometer, Turbine Flow Meters, Telemetry, Orsat apparatus, 5 Gas Analysers, Smoke meters, Gas Chromatography.

Module V

Microprocessors and Computers in measurement, Data logging and data acquisition (DAQ) system. Analog to Digital (A-D) and Digital to Analog Conversion (DAC). Pulse Code Modulation (PCM), 4-bit DAC convertor, R- 2R Ladder DAC.

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	**8 Hours**
1.1	Measurement characteristics, Measurement and Instrument Classifications	**3**
1.2	Characteristics of Instruments – Static and dynamic Measurements	**2**
1.3	Errors in Measurements, Systematic and Random errors, Uncertainty, Selection of measuring instruments	**2**
1.4	Reliability of Measuring instruments	**1**
2	**Module 2**	**8 Hours**
2.1	Measurement of Pressure, Various Pressure sensing elements	**1**
2.2	Bellows Inductance, Resistance types, Capacitive Pressure Transducers, Piezoelectric and Potentiometric Pressure Transducers, Strain gauge pressure sensors.	**3**
2.3	Bridgeman Gauge for Very High-Pressure Measurement. Vacuum Measurement and McLeod gauge for very Low-Pressure Measurement	**2**
2.4	Pirani Gauge. Calibration Process, Dead weight Tester	**2**
3	**Module 3**	**8 Hours**
3.1	Measurement of Temperature, Thermometers, Thermometers Thermocouple	**3**
3.2	Resistance Temperature Detector (RTD), Thermistor, Bi-metallic Thermometers. Thermo-electric Pyrometers, Total radiation Pyrometers	**2**
3.3	Optical Pyrometers Pressure Thermometers, Infrared Thermometers, Temperature Calibration RTD and Thermocouple calibration	**3**
4	**Module 4**	**8 Hours**
4.1	Advance Measurement Techniques- Shadowgraph, Schlieren imaging, Interferometer, Laser Doppler Anemometer,	**4**
4.2	Particle Image Velocimetry Hot Wire Anemometer, Turbine Flow Meters, Telemetry, Orsat apparatus, 5 Gas Analysers, Smoke meters, Gas Chromatography	**4**
5	**Module 5**	**8 Hours**
5.1	Microprocessors and Computers in measurement, Data	**3**

	logging and data acquisition (DAQ) system	
5.2	Analog to Digital (A-D) and Digital to Analog Conversion (DAC).	**2**
5.3	Pulse Code Modulation (PCM), 4-bit DAC convertor, R-2R Ladder DAC.	**1**

Reference Books

1. Holman, J.P., Experimental methods for engineers, McGraw-Hill, 1988.
2. Alan S Morris, Reza Langari, Measurement and Instrumentation Theory and Application, Academic Press 2016.
3. Raman, C.S. Sharma, G.R., Mani, V.S.V., Instrumentation Devices and Systems, Tata McGraw-Hill, New Delhi, 1983.
4. Doeblin, Measurement System Application and Design, McGraw-Hill, 1978.
5. Morris. A.S, Principles of Measurements and Instrumentation Prentice Hall of india.
6. N.V. RAGHAVENDRA and L. KRISHNAMURTHY, Engineering Metrology and Measurements, Oxford University Press 2013.

PROGRAM ELECTIVE II

CODE	SOLAR THERMAL ENERGY SYSTEMS	CATEGORY	L	T	P	CREDIT
222EME030		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: This course introduces fundamentals of solar energy, its collection and storage, and the principles of solar thermal energy technologies.

Course Outcomes:

After the completion of the course the student will be able to,

CO 1	Explain the basic concepts of solar energy
CO 2	Estimate the amount of solar energy available at any time at a particular location on earth
CO 3	Differentiate various types of solar energy collectors
CO 4	Compute the performance of solar air and water heaters
CO 5	Describe various methods of storing solar energy
CO 6	Judge a suitable solar thermal energy system for a given application

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1		2	3				
CO 2	1	2	3				
CO 3	1		3				
CO 4	1		3				
CO 5		2	3				
CO 6	1	2	3				

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25 %
Analyse	50 %
Evaluate	25 %
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation:**15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: **60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; **Part A and Part B**. **Part A** will contain **5** numerical/short answer questions with 1 question from each module, having **5 marks for each question** (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. **Part B** will contain **7** questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. **Each question can carry 7 marks**.

Model Question Paper

Reg.No.........................

Name:.........................

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
M.Tech Degree Examination, Month & Year
FIRST SEMESTER

SOLAR THERMAL ENERGY SYSTEMS

Time : 2.5 Hours Maximum : 60 Marks

(Heat and mass transfer data book and attested list of correlations/tables are permitted)

PART A (5 x 5 = 25 marks)
(Answer all questions. Each question carries 5 marks)

1 Define solar constant. How the value of solar constant is estimated?

2 Explain collector efficiency factor and its significance.

3 What is meant by top loss coefficient? How it is estimated?

4 Explain the variation of concentration and temperature gradients in a solar pond with appropriate diagrams.

5 Describe multi-effect distillation system with a neat sketch

PART B (5 x 7 = 35 marks)
Answer any five questions. Each question carries 7 marks

6 Describe the components and working of a pyrheliometer.

7. Estimate the daily global radiation on a horizontal surface at Thiruvananthapuram (8°29'7.8"N, 76°56'57.26"E) during the month of September. Take constants a = 0.37, b = 0.39 and average sunshine hour for the day as 8.5 for the location.

8. Describe any two tracking modes of concentrating solar collectors with neat sketches.

9. In a solar power plant, many heliostats at ground level are used to direct concentrated solar flux to a cylindrical receiver. The diameter of the receiver is 7 m, length 12 m and emissivity 0.2. If all of the incident solar flux is absorbed by the receiver and a surface temperature of 800 K is

maintained, estimate the rate of heat loss from the receiver. Assume ambient air is still at a temperature of 300 K and neglect irradiation from surroundings. If the corresponding value of solar flux is 10^5 W/m^2, calculate the collector efficiency.

10. Explain a matrix air heater with a neat sketch. Give the energy balance equation for air stream flowing through a solar air heater and describe each terms.
11. The absorber plate and adjoining cover plate of a flat-plate solar collector are at 70 and 35 ^oC, respectively and are separated by an air space of 0.05 m. What is the rate of free convection heat transfer per unit surface area between the two plates if they are inclined at an angle of 60 ^oC from the horizontal?
12. Describe energy storage in packed beds with a neat sketch. Write the energy balance equations for fluid and solid in packed beds with appropriate assumptions.

Syllabus

Module 1

Solar radiation: Energy from the sun, spectral distribution of extra-terrestrial radiation, solar constant, revolution of earth, seasons, Sun-earth angles, diffuse and direct radiation, solar radiation under actual conditions, air mass, solar radiation on horizontal and inclined surfaces, shading, sun-path diagram, concept of time, standard time, solar time, day length, hourly, daily and monthly average solar radiation, measurement of solar radiation, Pyrheliometer, Pyranometer, Sunshine recorder

Module 2

Collection of Solar Energy: Flat plate collectors, classification, construction, heat transfer coefficients, optimization of heat losses, analysis of flat plate collectors, heat removal factor, collector efficiency factor, testing of collectors, concentrating collectors, classification of concentrators, modes of solar tracking, Parabolic trough collector, thermal analysis, compound parabolic concentrators, parabolic dish collector, central receiver tower

Module 3

Solar air and water heaters: Solar air heaters, description and classification, thermal analysis, air heater above the collector surface, air heaters with flow on both sides of absorbers, air heater with finned absorbers, porous absorber, Solar water heaters, description and classification, thermal analysis, natural circulation and forced circulation water heater, integral collector storage systems. Testing and rating of solar water heaters, economics of solar water heating

Module 4

Solar energy storage: Thermal, mechanical, electrical and chemical methods of storage, quality, capacity and duration of storage, Sensible heat storage- liquid, solid, packed bed storage. Latent heat storage- phase change materials for storage, Energy storage in building materials, long term energy storage using solar ponds, sand, molten silicon, gravity-based energy storage

Module 5

Solar thermal systems: Passive solar house, direct and indirect thermal gain, solar driven cooling, ventilation, solar drying, solar cooking, solar distillation, solar thermal power plant, solar thermal energy for process heating

Course Plan

No	Topic	No. of Lectures
1	**Solar radiation**	
1.1	Energy from the sun, spectral distribution of extra-terrestrial radiation, solar constant, revolution of earth, seasons	1
1.2	Sun-earth angles, diffuse and direct radiation, solar radiation under actual conditions, air mass, solar radiation on horizontal and inclined surfaces, shading, sun-path diagram	4
1.3	Concept of time, standard time, solar time, day length, hourly, daily and monthly average solar radiation	2
1.4	Measurement of solar radiation, Pyrheliometer, Pyranometer, Sunshine recorder	1
2	**Collection of Solar Energy**	
2.1	Flat plate collectors, classification, construction, heat transfer coefficients, optimization of heat losses, analysis of flat plate collectors, heat removal factor, collector efficiency factor, testing of collectors	3
2.2	Concentrating collectors, classification of concentrators, modes of solar tracking	2
2.3	Parabolic trough collector, thermal analysis, compound parabolic concentrators, parabolic dish collector, central receiver tower	3
3	**Solar air and water heaters**	
3.1	Solar air heaters, description and classification, thermal analysis, air heater above the collector surface, air heaters with flow on both sides of absorbers, air heater with finned absorbers, porous absorber	3
3.2	Solar water heaters, description and classification, thermal analysis, natural circulation and forced circulation water heater, integral collector storage systems.	3
3.3	Testing and rating of solar water heaters, economics of solar water heating	2
4	**Solar energy storage**	
4.1	Thermal, mechanical, electrical and chemical methods of storage, quality, capacity and duration of storage	3
4.2	Sensible heat storage- liquid, solid, packed bed storage. Latent heat storage- phase change materials	3

	for storage	
4.3	Energy storage in building materials, long term energy storage using solar ponds, sand, molten silicon, gravity-based energy storage	2
5	**Solar thermal systems**	
5.1	Passive solar house, direct and indirect thermal gain, solar driven cooling, ventilation	3
5.2	Solar drying, solar cooking, solar distillation	3
5.3	Solar thermal power plant, solar thermal energy for process heating	2

Reference Books

1. S.P Sukhatme, Solar Energy - Principles of Thermal Collection and Storage, Tata Mc-Graw Hill Publishing Company Limited
2. John A. Duffie, William A. Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons, Inc.
3. Ibrahim Dinçer, Marc A. Rosen, Thermal Energy Storage: Systems and Applications, 3rd Edition, Wiley
4. G.N.Tiwari, Solar Energy: Fundamentals, Design, Modelling and Applications, Narosa Publishing House

CODE 221EME031	ENERGY CONSERVATION IN THERMAL ENGINEERING	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: Make the students to model heat transfer problems by integrating heat transfer physics with mathematical tools

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs.

After the completion of the course the student will be able to

CO 1	Explain the fundamentals of energy, its utilization and management
CO 2	Develop thermodynamic and economic analysis of energy utilization
CO 3	Determine waste heat recovery and optimum boiler operation
CO 4	Explain environmental aspects of energy utilization

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3		3		3		
CO 2	3		3		3		
CO 3	2		3		3		
CO 4					3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	50 %
Analyse	25 %
Evaluate	20 %
Create	5 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: 60 marks

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

Reg. No:______________

Name:________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M. TECH DEGREE EXAMINATION, MONTH & YEAR FIRST SEMESTER

221EME031 ENERGY CONSERVATION IN THERMAL ENGINEERING

Time: 2.5 hrs. Max. Marks: 60

PART A (5 x 5 = 25 Marks)

(Answer all questions, Each question carries 5 marks)

1. Comment on the global energy scenario
2. Write short notes on energy conservation schemes
3. Discuss the term investment optimization
4. Discuss the term thermodynamic availability analysis
5. Mention the uses of heat pumps and its working

PART B (5 x 7 = 35 Marks)

(Answer any five questions, each question carries 7 marks)

6. Discuss the environmental aspects of energy utilization and public health issues related to environmental pollution
7. Explain the methods used for energy conservation in space conditioning
8. What are the methods used for optimum pipe size selection
9. Explain the term total site cogeneration potential
10. Mention the advantages and disadvantages of combustion air preheating
11. Explain the methods used to improve process operations
12. What are the methods to improve the boiler efficiency

Syllabus

Module I

Basics of energy, Types of energy and its utilization, Energy characteristics. Global energy scenario, India energy scenario, Types of energy and its utilization, Energy Characteristics, Energy measures. Fundamentals of environment, Water cycle, Oxygen cycle, Carbon cycle, Nitrogen cycle, phosphorous cycle. Bio-diversity, Environmental aspects of energy utilization, public health issues related to environmental pollution

Module II

Definition of energy management, Energy conservation schemes. Optimizing steam usage, Waste heat management, Insulations, Optimum selection of pipe size. Energy conservation in space conditioning, Energy and cost indices, Energy diagrams. Energy auditing, Thermodynamic availability analysis, Thermodynamic efficiencies, Available energy.

Module III

Thermodynamics and economics, Systematic approach to steam pricing, Pricing other utilities. Investment optimization, Limits of current technology, Process improvements, Characterizing energy use, Optimum performance of existing facilities, Steam trap principles Effective management of energy use, Overall site Interactions, Total site cogeneration potential.

Module IV

Thermodynamic analysis of common unit operations. Heat exchange - Expansion - Pressure let down, Mixing, Distillation, Combustion air pre-heating. Systematic design methods, Process synthesis, Application to cogeneration system, Thermo-economics, Systematic optimization, Improving process operations, Separation, Heat transfer, Process machinery, System interaction and economics.

Module V 8

Potential for waste heat recovery, Direct utilization of waste heat boilers, Use of heat pumps, Improving boiler efficiency, Industrial boiler inventory. Use of fluidized beds, Potential for energy conservation, Power economics, General economic problems, Load curves, Selections of plants, Energy rates

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	**5**
1.1	Basics of energy, Types of energy and its utilization, Energy characteristics	**2**
1.2	Global energy scenario, India energy scenario, Types of energy and its utilization, Energy Characteristics, Energy measures	**1**
1.3	Fundamentals of environment, Water cycle, Oxygen cycle, Carbon cycle, Nitrogen cycle, Phosphorous cycle	**1**
1.4	Bio-diversity, Environmental aspects of energy utilization, public health issues related to environmental pollution	**1**
2	**Module 2**	**8**
1.1	Definition of energy management, Energy conservation schemes	**2**
1.2	Optimizing steam usage, Waste heat management, Insulations, Optimum selection of pipe size	**2**
1.3	Energy conservation in space conditioning, Energy and cost indices, Energy diagrams	**2**
1.4	Energy auditing, Thermodynamic availability analysis, Thermodynamic efficiencies, Available energy	**2**
3	**Module 3**	**8**
3.1	Thermodynamics and economics, Systematic approach to steam pricing, Pricing other utilities.	**2**
3.2	Investment optimization, Limits of current technology, Process improvements	**2**
3.3	Characterizing energy use, Optimum performance of existing facilities, Steam trap principles	**2**
3.4	Effective management of energy use, Overall site Interactions, Total site cogeneration potential	**2**
4	**Module 4**	**11**
4.1	Thermodynamic analysis of common unit operations	**1**
4.2	Heat exchange - Expansion - Pressure let down, Mixing, Distillation, Combustion air pre-heating	**4**
4.3	Systematic design methods, Process synthesis, Application to cogeneration system,	**3**
4.4	Thermo-economics, Systematic optimization, Improving process operations, Separation, Heat transfer, Process machinery, System interaction and	**3**

	economics.	
5	**Module 5**	**8**
5.1	Potential for waste heat recovery	**1**
5.2	Direct utilization of waste heat boilers, Use of heat pumps	**2**
5.3	Improving boiler efficiency, Industrial boiler inventory	**2**
5.4	Use of fluidized beds, Potential for energy conservation, Power economics, General economic problems, Load curves, Selections of plants, Energy rates	**3**

Reference Books

1. W.F. Kenney: Energy Conservation in the Process Industries, Academic Press, 1984
2. A.P.E. Thummann: Fundamentals of Energy Engineering, Prentice Hall, 1984
3. M.H. Chiogioji: Industrial Energy Conservation, Marcel Dekker, 1979
4. W. R. Murphy and G. McKay: Energy Management, Butterworth-Heinemann, 2001
5. F.B. Dubin: Energy Conservation Standards, McGraw Hill, 1978
6. C. S. Rao: Environmental Pollution Control Engineering, Wiley Eastern, 1992
7. Y. Anjaneyulu: Air Pollution and Control Technologies, Allied Publishers, 2002

CODE	BIOMASS ENERGY AND APPLICATIONS	CATEGORY	L	T	P	CREDIT
221EME032		PROGRAM ELECTIVE 2	3	0	0	3

Preamble:Nil

Course Outcomes:

After the completion of the course the student will be able to:

CO 1	Develop a critical thinking about sustainability and resilience
CO 2	Identify potential biomass feedstocks and suggest the apt conversion process
CO 3	Summarize the existing and emerging biomass to energy solutions
CO 4	Compute simple and complex bio-energy problems
CO 5	Determine potential solutions for energy needs through bioenergy technologies

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			3		3		
CO 2					3		
CO 3		2		3			
CO 4				3			
CO 5			3				

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	50%
Analyse	25%
Evaluate	20%
Create	5%

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): **15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 No.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: **60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. **Part A** will contain **5 numerical/short answer** questions with 1 question from each module, having **5 marks for each question** (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. **Part B** will contain **7 questions** (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry **7 marks.**

Model Question paper

Reg. No:______________
Name:________________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

M. TECH DEGREE EXAMINATION, MONTH & YEAR

FIRST SEMESTER

Biomass Energy and Applications

Time: 2.5 hrs Marks: 60

Part A (5 x 5 = 25 Marks)
Answer all questions. Each question carries 5 marks

1. Explain in your own words the greenhouse effect and the human contribution to it.
2. Differentiate between aerobic and anaerobic digestion process.
3. The tar content in a down-draft biomass gasifier is much low as compared to an up-draft type. Explain.
4. Differentiate between grey, blue and green hydrogen.
5. In which ways can mankind adapt to climate change impacts, and which roles can biomass play in such adaptations?

Part B (5 x 7 = 35 Marks)
Answer any five questions. Each question carries 7 marks

6. Write in detail about the power sector in India and the position of India in renewable energy sector. Discuss the various viable options for biomass to energy applications.
7. a) Comment about the environmental, Socio-political benefits & economic issues of biomass conversion.

   b) Compare the performance of traditional stoves with gasifier stoves.
8. Compare the thermodynamic efficiency of electricity generation from biomass through the two different routes:

   (i)Biomass is gasified with a cold gas efficiency of 80% and the product gas is burnt to produce hot flue gas at 1250 ^{o}C, which expands in a gas turbine to 650 ^{o}C. Waste gas from the gas turbine enters a heat recovery steam generator that produces steam at 400 ^oC. This steam expands to 100 ^oC in a steam turbine. Both turbines are connected to electricity generators. Neglect losses in the generators.

(ii)Biomass is combusted in a boiler with 90% thermal efficiency (on LHV basis) to generate steam, which expands in a steam turbine from 600 ^oC to 100 ^oC driving an electrical generator.

9. The gasification of a biomass yields M kg/s product gas, with the production of its individual constituents as follows:

   Hydrogen: M_H, kg/s

   Carbon monoxide: M_{CO}, kg/s

   Carbon dioxide: M_{CO2}, kg/s

   Methane: M_{CH4}, kg/s

   Other hydrocarbon (e.g., C_3H_8): M_{HC}, kg/s

   Nitrogen: M_N, kg/s

   Moisture: kg/s

   Find the composition of the product gas in mass fraction, mole fraction, and other fractions.

10. a) Discuss about biochemical ethanol production and its applicability as transportation fuel.

    b) Write notes on biomass characterization techniques.

11. Discuss the various technologies for biogas enrichment. With a neat sketch, explain in detail about the water scrubbing method for biogas enrichment.

12. An SOFC operating on CNG produces 1 kW electric power with an electrical efficiency of 55% based on the LHV of natural gas.

    i) Calculate the heat released by SOFC per unit time.

    ii) If 60% of the available heat can be recovered by heating water from 25 to 75 ^oC, calculate the amount of hot water produced when the SOFC is operated for 10 hours.

Syllabus

Module 1 (7 hrs)

Energy, Environment & Climate: Biomass for a sustainable energy system

Present energy scenario, Reserves of energy resources, Fossil fuels and environmental issues. Impact of Emission on Environment & Climate, Sources of emission, Types of Emissions from various sectors (industry, power, human activities, agricultural activities), Emission estimation methodologies, Kyoto Protocol, Clean development mechanism, Concepts of Carbon credit. Energy from biomass: Potential, benefits & limitations Biomass availability, Bio-Energy Scenario, Technologies for Bioenergy conversion, Global and Indian Bio-Energy Potential

Module 2 (8 hrs)

Biomass—renewable energy from plants and animals

Biomass resources: Harvested and residue feedstocks. Biomass composition & properties: Physiochemical properties, Main structural organic constituents, Minor organic and inorganic compounds. Biomass characterisation – Analytical techniques, Biomass Physical pre-treatments. Renewable, Environmental, Socio-political benefits & Economic issues of biomass conversion.

Module 3 (9 hrs)

Biomass conversion: Thermochemical energy processes

Direct combustion, Cook stoves, Efficiency and emissions, Advanced biomass combustion devices. Torrefaction, Pyrolysis, Biochar production-various biochar applications. Gasification – Fundamentals, Gasifier types and design, Syngas applications, Syngas cleaning and conditioning for engine application.

Module 4 (8 hrs)

Biomass conversion: Biochemical processes

Anaerobic digestion: factors affecting the biogas yield. Bio-methanation technology: classification of digesters, working principle and design layouts, Calculations for digester sizing, biogas storage and utilization. Fermentation – bioethanol production, Dark fermentation. Bio-diesel from edible and non-edible oils, Characteristics and technical aspects of bio-diesel engine utilization.

Module 5 (8 hrs)

Emerging technologies, Process modelling and simulation

Biogas/Syngas enrichment technologies – PSA, membranes, water scrubbing, etc.

Basics of hydrogen fuel, Bio-hydrogen production process and applications. Process modelling and simulation: Combustion, Gasification, Reforming, Thermochemical/Biochemical process coupled with GT, ICE, Fuel cells, etc. Basics of LCA of bioenergy systems.

Course Plan

No	Topic	No. of Lectures
1	**Energy, Environment & Climate: Biomass for a sustainable energy system**	
1.1	Present energy scenario, Reserves of energy resources, Fossil fuels and environmental issues	2
1.2	Impact of Emission on Environment & Climate, Sources of emission, Types of Emissions from various sectors (industry, power, human activities, agricultural activities), Emission estimation methodologies, Kyoto Protocol, Clean development mechanism, Concepts of Carbon credit.	3
1.3	Energy from biomass: Potential, benefits & limitations Biomass availability, Bio-Energy Scenario, Technologies for Bioenergy conversion, Global and Indian Bio-Energy Potential	2
2	**Biomass—renewable energy from plants and animals**	
2.1	Biomass resources: Harvested and residue feedstocks Biomass composition & properties: Physiochemical properties, Main structural organic constituents, Minor organic and inorganic compounds.	3
2.2	Biomass characterisation – Analytical techniques Biomass Physical pre-treatments	3
2.3	Renewable, Environmental, Socio-political benefits & Economic issues of biomass conversion.	2
3	**Biomass conversion: Thermochemical energy processes**	
3.1	Direct combustion, Cook stoves, Efficiency and emissions, Advanced biomass combustion devices.	2
3.2	Torrefaction, Pyrolysis Biochar production-various biochar applications.	2
3.3	Gasification – Fundamentals, Gasifier types and design, Syngas applications, Syngas cleaning and conditioning for engine application.	5
4	**Biomass conversion: Biochemical processes**	
4.1	Anaerobic digestion: factors affecting the biogas yield.	2
4.2	Bio methanation technology: classification of digesters, working principle and design layouts, Calculations for digester sizing, biogas storage and utilization.	3
4.3	Fermentation – bioethanol production, Dark fermentation.	3

	Bio-diesel from edible and non-edible oils, Characteristics and technical aspects of bio-diesel engine utilization.	
5	**Emerging technologies, Process modelling and simulation**	
5.1	Biogas/Syngas enrichment technologies – PSA, membranes, water scrubbing, etc.	3
5.2	Basics of hydrogen fuel, Bio-hydrogen production process and applications.	2
5.3	Process modelling and simulation: Combustion, Gasification, Reforming, Thermochemical/Biochemical process coupled with GT, ICE, Fuel cells, etc. Basics of LCA of bioenergy systems.	3

Reference Books

1. Understanding Clean Energy & Fuels from Biomass. H.S. Mukunda, Wiley India Pvt. Ltd, First edition, 2011, ISBN: 9788126529698

2. Biomass as a Sustainable Energy source for the Future – Fundamentals of Conversion Processes. Edited by Wiebren de Jong & J. Ruud van Ommen, John Wiley & Sons, 2015, ISBN 978-1-118-30491-4

3. Biomass for Renewable Energy, Fuels, and Chemicals. D.L. Klass, Academic Press

4. Biomass Gasification, Pyrolysis and Torrefaction: Practical Design and Theory, Prabir Basu, Academic Press (2013), Second edition, ISBN: 978-0-12-396488-5

5. Biomass, Energy and Environment: A developing country perspective from India. Ravindranath N H, Hall D O, Oxford University Press

6. Biogas Systems: Principles and Applications. K.M.Mittal, New Age Publications

7. The Inter-governmental Panel on Climate Change (IPCC) guidelines

8. Hydrogen and Fuel Cells: Emerging Technologies and Applications, Bent Sorensen & Giuseppe Spazzafumo, Academic Press (2018), 3rd Edition, ISBN: 9780081007082.

9. Alternative Transportation Fuels: Utilization in Combustion Engines, Babu M.K.G., Subramanian K.A, CRC Press (2013).

CODE	MATERIALS ENGINEERING FOR THERMAL AND ENERGY SYSTEMS	CATEGORY	L	T	P	CREDIT
221EME033		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: Materials-Engineering holds the key for advancements in energy conversion technologies envisaged for the future. Research and developments in materials engineering related to photovoltaics, fuel cells, battery technologies, and aspects of nanotechnology would spearhead human quest for safe, economic and enhanced energy production, in the near future. Any higher academic endeavour focussing on energy systems would require knowledge on these areas, both as part of knowledge building, as well as to contribute by way of research and development outputs in the form of publications and patents.

Course Outcomes: After the completion of the course the student will be able to

CO 1	Summarize the advancements in Materials Engineering related to existing energy technologies.
CO 2	Discuss the aspects of solar Photovoltaic conversion and the latest developments in that area.
CO 3	Compare the latest trends in Fuel Cells Technology.
CO 4	Describe the Materials Engineering aspects in energy storage.
CO 5	Explain the role of Nanotechnology in Energy Harvesting.

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1	1		3				
CO 2	1		3				
CO 3	1		3				
CO 4	1		3				
CO 5	1		3				

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	35%
Analyse	35%

Evaluate	30%
Create	

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: **40 marks**

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred):**15 marks**

Course based task/Seminar/Data collection and interpretation: **15 marks**

Test paper, 1 no.: **10 marks**

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern:

End Semester Examination: **60 marks**

The end semester examination will be conducted by the respective College. There will be two parts; **Part A and Part B**. **Part A** will contain **5** numerical/short answer questions with 1 question from each module, having **5 marks for each question** (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. **Part B** will contain **7** questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. **Each question can carry 7 marks**

.

Model Question Paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M. TECH DEGREE EXAMINATION,

221EME033 Materials Engineering for Thermal and Energy Systems

Time: 2.5 hrs Marks: 60

Part A (5 x 5 = 25 Marks)

Answer all questions. Each question carries 5 marks

1. Write a short note on applicability of Phase Change Materials for Energy Storage.
2. Make a short note on the conversion efficiency of Solar Photovoltaics
3. What is Hydrogen Economy?
4. Differentiate between reversible and irreversible cells.
5. Make a short note on application of Nano-materials in energy storage technology.

Part B (5 x 7 = 35 Marks)

Answer any five questions. Each question carries 7 marks

6. Discuss the role of Research & Development in Materials Science & Engineering in deciding the future of newer energy harvesting technologies.
7. Describe the Materials Science challenges in high temperature energy conversion.
8. Prepare an essay on the recent advancements in solar photo voltaic energy conversion.
9. Compare and contrast different fuel cell technologies.
10. Compare charging and discharging characteristics of

Lead-acid and Lithium-ion batteries

11. Make an essay on application of carbon nanotubes in energy conversion
12. Describe the role of Nanotechnology in batteries, solar energy conversion and fuel cells.

SYLLABUS

Module-1: Improvements in Materials Engineering for existing energy technologies: Material Challenges in high temperature power conversion-Corrosion resistant alloys for high temperature power conversion. Strong, light weight composites for wind turbine blades. Advances in Materials engineering for improved combustion efficiencies. Phase change materials as energy storage systems. Material challenges in Biofuel technology. Advances in Materials for Nuclear Engineering. New Materials for drilling and piping in Enhanced Geothermal Systems (EGS). (7 Hours)

Module-II: Basics: solar spectra, Fluorescence; Electron transfer: Factors affecting electron transfer; Different types and approaches: organic solar cells, Bilayer, Bulk heterojucntion, Polymer solar cells, Hybrid solar cells (Non-electrochemical), Materials for photovoltaics, Efficiency, Limiting factors. High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III-V, II-VI thin-film solar cells (GaAs, Cu(In,Ga)Se2, CdTe) Nano-, micro- and poly-crystalline Si for solar cells, mono-micro silicon composite structure . (9 Hours)

Module-III: Basics, Various types; Alkaline FC, Phosphoric acid FC, Molten Carbonate FC, Solid oxide FC, Polymer Exchange Membrane FC, Direct methanol FC; Mass and thermal management, Fluid flow characteristics, Reforming; Internal/external, efficiency, Role of internal resistance, General causes for failure; Hydrogen economy, Hydrogen storage: Super/ultracapacitors: Advances in electrochemical systems, Semiconductor electrochemistry, Photoelectrochemical cells. (8 Hours)

Module-IV: Reversible cells and irreversible cell reactions, Primary and Secondary cells, Different types of batteries and examples: Leclanche/Dry/Alkaline cell, Silver cell, Mercury cell, Lead-acid battery: discharge and charging characteristics, overcharging, safety and design; Edison Cell, Ni-Cd battery, Ni Metal Hydride (NiMH) battery, Ni-Hydrogen battery, Sodium-Sulfur battery, Lithium-ion/Lithium-polymer battery, Discharge characteristics, Energy density. (8 Hours)

Module-V: Introduction to nanotechnology and nanomaterials science, properties of nanomaterials, fabrication of nanomaterials, top down and bottom-up methods-sputtering – ALD – MBE. Concepts of quantum and phonon confinement, optical and vibrational properties of nanomaterials. Carbon nanomaterials, CNT, C60 graphene, CQD, application of nanomaterials in energy conversion, nanofabrication in Si solar cell, Thin film solar cell, DSSC, PEC and H2 generation. Nanomaterials for energy storage. Application of Nanotechnology for Batteries, Solar, and Fuel Cells. (8 Hours)

Course Plan

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Improvements in Materials Engineering for existing energy technologies	1
1.2	Material Challenges in high temperature power conversion-Corrosion resistant alloys for high temperature power conversion	1
1.3	Strong, light weight composites for wind turbine blades. Advances in Materials engineering for improved combustion efficiencies	1
1.4	Phase change materials as energy storage systems. Material challenges in Biofuel technology.	2
1.5	Advances in Materials for Nuclear Engineering. New Materials for drilling and piping in Enhanced Geothermal Systems (EGS).	2
2	**Module 2**	
2.1	Basics: solar spectra, Fluorescence; Electron transfer	1
2.2	Factors affecting electron transfer; Different types and approaches: organic solar cells, Bilayer, Bulk hetero junction, Polymer solar cells, Hybrid solar cells (Non-electrochemical), Materials for photovoltaics, Efficiency, Limiting factors.	4
2.3	High efficiency solar cells, PERL Si solar cell, III-V high efficiency solar cells, GaAs solar cells, tandem and multi-junction solar cells, solar PV concentrator cells and systems, III-V, II-VI thin-film solar cells (GaAs, Cu (In,Ga)Se2, CdTe) Nano-, micro- and poly-crystalline Si for solar cells, Mono-micro silicon composite structure	3
3	**Module 3**	
3.1	Basics, Various types; Alkaline FC, Phosphoric acid FC, Molten Carbonate FC, Solid oxide FC, Polymer Exchange Membrane FC, Direct methanol FC	2
3.2	Mass and thermal management, Fluid flow characteristics	1
3.3	Reforming; Internal/external, efficiency, Role of internal resistance	1
3.4	General causes for failure; Hydrogen economy, Hydrogen storage: Advances in electrochemical systems, Semiconductor electrochemistry, Photoelectrochemical cells.	2

3.5	Super/ultracapacitors: Advances in electrochemical systems, Semiconductor electrochemistry, Photoelectrochemical cells)	2
4	**Module 4**	
4.1	Reversible cells and irreversible cell reactions	1
4.2	Primary and Secondary cells, Different types of batteries and examples: Leclanche/Dry/Alkaline cell, silver cell, Mercury cell, Lead-acid battery:	2
4.3	Discharge and charging characteristics, overcharging, safety and design;	2
4.4	Edison Cell, Ni-Cd battery, Ni Metal Hydride (NiMH) battery, Ni-Hydrogen battery, Sodium-Sulfur battery, Lithium-ion/Lithium-polymer battery, Discharge characteristics, Energy density. (8 Hours)	3
5	**Module 5**	
5.1	Introduction to nanotechnology and nanomaterials science, properties of nanomaterials	2
5.2	Fabrication of nanomaterials, top down and bottom-up methods-sputtering – ALD – MBE.	2
5.3	Quantum and phonon confinement, optical and vibrational properties of nanomaterials. Carbon nanomaterials, CNT, C60 graphene, CQD	2
5.4	Application of nanomaterials in energy conversion, nanofabrication in Si solar cell, thin film solar cell, DSSC, PEC and H2 generation. Nanomaterials for energy storage. Application of Nanotechnology for Batteries, Solar, and Fuel Cells	2

Reference Books

1. Solar Photovoltaics: Fundamentals, Technologies and Applications, C S Solanki, 2nd Edition, PHI Learning, 2013

2. Recent Trends in Fuel Cell Science and Technology, Suddhasatwa Basu, 1st edition, Springer-Verlag New York 2007

3. Energy Storage: Fundamentals, Materials and Applications, Robert Huggins, Springer, 2nd ed., 2016

4. M. D. Ventra, S. Evoy and J. R. Heflin, "Introduction to Nanoscale Science and Technology", Kluwer Academic Publishers, 2004.