DARBHAMGA COLLEGE OF ENGINEERING

DARBHANGA,BIHAR

COURSE FILE

OF

HEAT AND MASS TRANSFER

(02 1616)

FACULTY NAME:

MADHAV RAM

ASSISTANT PROFESSOR,

DEPARTMENT OF MECHANICAL ENGINEERING

Vision of the Mechanical Engineering Department :

To produce quality mechanical engineers to pursue higher studies in thermal, manufacturing and design engineering, serve the national and multinational companies.

Mission of the Mechanical Engineering Department:

M1: To produce quality mechanical engineers through a good teaching learning ambience.

M2: To promote the graduates for studies and research in mechanical engineering.

M3: Graduates will serve the nation through public services.

M4: To produce mechanical engineers to apply their knowledge and skills while working as a professional engineer keeping ethical values.

Program Educational Objectives (PEOs) :

PEO 1	The graduates will demonstrate the knowledge and skills of mechanical engineering to obtain the solution to the complex design engineering problems.
PEO 2	The graduate will apply the mechanical engineering concepts while pursuing academic and research activities.
PEO 3	The graduates will showcase the professional skill with keeping societal ethical values.

Program Outcomes (POs) :

PO 1	**Engineering knowledge:** An ability to apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to get the solution of the engineering problems.
PO 2	**Problem analysis:** Ability to Identify, formulates, review research literature, and analyze complex engineering problems.
PO 3	**Design/development of solutions**: Ability to design solutions for complex engineering problems by considering social, economic and environmental aspects
PO 4	**Conduct investigations of complex problems:** Use research-based knowledge to design, conduct analyze experiments to get valid conclusion.

PO 5	**Modern tool usage:** ability to create, select, and apply appropriate techniques, and to model complex engineering activities with an understanding of the limitations.
PO 6	**The engineer and society:** Ability to apply knowledge by considering social health, safety, legal and cultural issues.
PO 7	**Environment and sustainability:** Understanding of the impact of the adopted engineering solutions in social and environmental contexts.
PO 8	**Ethics:** Understanding of the ethical issues of the Mechanical engineering and applying ethical principles in engineering practices.
PO 9	**Individual and teamwork:** Ability to work effectively as an individual or in team, as a member or as a leader.
PO 10	**Communication:** An ability to communicate clearly and effectively through different modes of communication.
PO 11	**Project management and finance:** Ability to handle project and to manage finance related issue
PO 12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning.

Program Specific Outcomes (PSOs) :

PSO 1	Students should able to understand and apply the concept in the field of design, manufacturing, and in thermal areas.
PSO 2	Students should able to learn and apply the software like AutoCAD, Ansys, Catia for various applications.

Scope and Objectives of the Course

This course is designed to cover the basic principles of heat transfer and to present a wealth of real-world engineering examples to give students a feel for how heat transfer is applied in engineering practice. The course curriculum focused to leads students toward a clear understanding and firm grasp of the basic principles of heat transfer and to encourage creative thinking and development of deeper understanding and intuitive feel for heat transfer by emphasizing the physics and physical arguments. It has broad application area ranging from biological systems to common household appliances, residential and commercial buildings, industrial processes, electronic devices and food processing.

The course outcomes are:

1. explain about the real time applications of solid medium heat transfer.
2. describe the real time applications of fluid medium heat transfer.
3. express the knowledge of design skills of heat exchangers.
4. illustrate the real time applications of radiation mode of heat transfer (no media).
5. relate the skill of mass transfer and its applications.

Course Syllabus :

02 1616	**Heat and Mass Transfer**	**3L:0T:3P**	**5 credits**

1. **Introduction :** Basic concepts and modes of heat transfer. **Lecture : 1**
2. **Conduction :** General three dimensional heat conduction equation; one dimensional steady heat conduction through composite plane walls; cylinders and spheres; critical radius of insulation. **Lecture : 6**
3. **Extended surface:** Heat transfer from extended surfaces of uniform cross section. **Lecture:4**
4. **Unsteady heat conduction :** one dimensional unsteady heat conduction, lumped system analysis; use of Heisler chart, periodic changes of surface temperature. **Lecture : 6**
5. **Convection :** Free and forced convection, hydrodynamic and thermal boundary layer equation over flat plate, laminar boundary layer analysis, fully developed heat transfer through smooth pipes, relation between fluid friction and heat transfer forced convection

correlations, laminar free convection on a vertical flat plate, empirical co-relations, application of dimensional analysis. **Lecture : 10**

6. **Heat exchanger:** Types, LMTD, effectiveness, NTU method, single and multipass. **Lecture : 5**
7. **Radiation :** Physical mechanism, radiation properties, black body radiation, grey body, kirchoff's law, Wien's displacement law, view factor, radiation exchange between infinite planes, radiation shields. **Lecture : 6**
8. **Mass transfer :** Fick's law, analogy between heat and mass transfer, equimolal counter diffusion, isothermal evaporation of water through stagnant air. **Lecture : 4**

Text Books :

1. Heat and mass transfer by Cengel
2. Heat and mass transfer by JP Holman
3. Heat transfer by SP Sukhatme
4. Heat and Mass Transfer Data Book by CP Kothandaraman

Reference Books :

1. Heat and mass transfer by PK Nag
2. Heat and mass transfer by Incorpera Dewit
3. Heat transfer by PS Ghosdastidar

Gate Syllabus :

Heat-Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept and electrical analogy, heat transfer through fins; unsteady heat conduction, lumped parameter system, Heisler's charts; thermal boundary layer, dimensionless parameters in free and forced convective heat transfer, heat transfer correlations for flow over flat plates and through pipes, effect of turbulence; heat exchanger performance, LMTD and NTU methods; radiative heat transfer, Stefan- Boltzmann law, Wien's displacement law, black and grey surfaces, view factors, radiation network analysis.

Time Table:

6th Semester, Mechanical Engineering ROOM NO. S-6								
Day/ time	**09:00-10:00**	**10:00-11:00**	**11:00-12:00**	**12:00-01:00**	**01:00-02:00**	**02:00-03:00**	**03:00-04:00**	**04:00-05:00**
MONDAY			**HMT**		**L**			
TUESDAY	**HMT**				**U**			
WEDNESDAY		**HMT**			**N**			
THURSDAY			**HMT**		**C**	**HMT LAB (M1)**		
FRIDAY					**H**	**HMT LAB (M2)**		
SATURDAY								
HMT : Heat and Mass Transfer (02 1616) **Course Coordinator : Madhav Ram**								

Student List: 6th Semester, Academic Year 2019-20, Batch (2017-21)

S. N.	Student Name	Registration No.	Roll No.
1	NITISH KUMAR	17102111001	17-M-67
2	MD. FAZAIL AKHTAR	17102111003	17-M-55
3	CHANDRAJEET AMAR	17102111004	17-M-60
4	KAMAL HASAN	17102111005	17-M-59
5	AMIT RAJ	17102111006	17-M-56
6	ANISHA KUMARI	17102111007	17-M-36
7	SIDDHARTH	17102111008	17-M-50
8	AYUSHMAN	17102111009	17-M-49
9	DEEPAK KUMAR MISHRA	17102111010	17-M-54
10	SACHIN KUMAR	17102111011	17-M-28
11	MD. RASHID ANWAR	17102111012	17-M-34
12	DHEERAJ KUMAR	17102111013	17-M-57
13	ANURAG KUMAR	17102111014	17-M-26
14	KUMAR SHIV GANESH	17102111015	17-M-08
15	DEVANAND KUMAR	17102111016	17-M-41
16	ATUL KUMAR KUSHWAHA	17102111017	17-M-16
17	SATISH KUMAR SAFI	17102111018	17-M-47
18	RAMAN KUMAR	17102111019	17-M-45
19	SAMEER VATS	17102111020	17- M-02
20	PRINCE KUMAR	17102111021	17-M-05
21	CHETAN SINHA	17102111022	17-M-07
22	JITENDRA KUMAR	17102111023	17-M-11
23	SANAUL HODA	17102111024	17-M-31
24	KINGS RAJ	17102111025	17-M-65
25	MD. ASAD JILANI	17102111026	17-M-44
26	PANKAJ KUMAR	17102111027	17-M-58
27	HARI MOHAN MISHRA	17102111028	17-M-63
28	MD. REHAN RAZA	17102111029	17-M-04
29	RAJA BABOO KUMAR	17102111030	17-M-52
30	RAJEEV KUMAR	17102111031	17-M-46
31	SONU KUMAR SAHU	17102111033	17-M-09
32	AMIT KUMAR	17102111035	17-M-10
33	MD. AFSARUL ISLAM	17102111036	17-M-32
34	AMAN KUMAR	17102111037	17-M-19
35	MAYASHANKAR THAKUR	17102111038	17-M-12

36	NITISH KUMAR	17102111039	17-M-14
37	ABHISHEK KUMAR	17102111040	17-M-20
38	KANHAIYA KUMAR PASWAN	17102111042	17-M-23
39	AMAR AJIT	17102111043	17-M-15
40	SURAJ KUMAR SUMAN	17102111044	17-M-51
41	ALEN KISHOR	17102111045	17-M-30
42	AMAN KUMAR ROY	17102111046	17-M-21
43	ANKIT KUMAR	17102111047	17-M-03
44	ASHUTOSH KUMAR	17102111048	17-M-18
45	MADHU SINHA	17102111049	17-M-68
46	SIDDHARTH KUMAR	17102111050	17-M-13
47	AJAY VIKASH	17102111051	17-M-29
48	NITISH KUMAR	17102111052	17-M-17
49	KUMARI SUKRITI PRIYA	17102111053	17-M-42
50	PRIYANKA BHARTY	17102111054	17-M-43
51	HARSHITA RANI	17102111055	17-M-53
52	SUNIL KUMAR	17102111056	17-M-61
53	KANHAIYA KUMAR	17102111057	17-M-66
54	ALKA KUMARI	17102111058	17-M-27
55	DEEPIKA	17102111060	17-M-06
56	RUPESH KUMAR SINGH	17102111061	17-M-22
57	AMIR CHANDRA SAHNI	17102111062	17-M-35
58	RAJA KUMAR MAHTO	17102111063	17-M-62
59	ROHIT KUMAR	18102111901	18-(LE)M-01
60	HARIOM KUMAR	18102111902	18-(LE)M-09
61	RATAN KUMAR	18102111903	18-(LE)M-03
62	MUNNA KUMAR	18102111904	18-(LE)M-08
63	SONU KUMAR	18102111905	18-(LE)M-02
64	BITTU KUMAR	18102111906	18-(LE)M-07
65	MANNU KUMAR THAKUR	18102111907	18-(LE)M-05
66	KUMAR RAHUL	18102111908	18-(LE)M-04
67	PRASHANT KUMAR	18102111909	18-(LE)M-11
68	PRADYUMAN KUMAR	18102111910	18-(LE)M-10
69	OM PRAKASH YADAV	18102111911	18-(LE)M-12

Institute / College Name :	Darbhanga College of Engineering, Darbhanga
Program Name	**B.Tech Mechanical Engineering**
Course Code	02 1616

Course Name	HEAT AND MASS TRANSFER		
Lecture / Tutorial (per week):	3/0	**Course Credits**	3
Course Coordinator Name	Madhav Ram		

Course Handout

1. Scope and Objectives of the Course

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10. relate the skill of mass transfer and its applications.

2. Textbooks

TB1: '*Heat and Mass Transfer*' by Yunus A. Cengel & Afshin J. Ghajar, 5th Edition, McGraw Hill Education, 2016.

TB2: '*Fundamentals of Heat and Mass Transfer*' by Frank P. incropera & Devid P. Dewitt, 7thEdition ,John Wiley, 2008.

3. Reference Books

RB1: '*Heat Transfer*' by J P Holman, 9thEdition, McGraw Hill Education, 2009.

RB2: '*Heat and Mass Transfer*' by D.S. Kumar , 7th Edition, Kataria & Sons, 2008.

RB3: '*Heat Transfer*' by SP Sukhatme.

RB4: '*Heat and Mass Transfer*' Data Book by CP Kothandaraman.

Other readings and relevant websites

S.No.	**Link of Journals, Magazines, websites and Research Papers**

1.	https://www.researchgate.net/publication/310482123-lecture-notes-on-heat-and-mass-transfer
2.	http://nptel.ac.in/downloads/112108149/
3.	http://www.mechcareer.in/study-material/heat-transfer/
4.	https://www.journals.elsevier.com/international-journal-of-heat-and-mass-transfer/recent-articles
5.	https://ocw.mit.edu/courses/mechanical-engineering/2-51-intermediate-heat-and-mass-transfer-fall-2008/study-materials/
6.	http://nptel.ac.in/courses/Webcourse-contents/IIScBANG/Heat%20and%20Mass%20Transfer/New_index1.html

Course Plan

Lecture Number	Date of Lecture	Topics	Web Links for video lectures	Text Book / Reference Book / Other reading material	Page numbers of Text Book(s)
1		**Introduction**		TB1, RB3	1-27
		Basic concepts and modes of heat transfer	https://cosmolearning.org/video-lectures/introduction-on-heat-and-mass-transfer/		
2-7		**Conduction**		TB1, RB2	67-112
		General three dimensional heat conduction equation; one dimensional steady heat conduction through composite plane walls; cylinders and spheres; critical radius of insulation.	https://cosmolearning.org/video-lectures/heat-conduction-i/		
		Assignment 1			
8-11		**Extended surface**		TB2, RB1	126-149
		Heat transfer from extended surfaces of uniform cross section.	https://cosmolearning.org/video-lectures/heat-		

			conduction-v/		
12-17		**Unsteady Heat Conduction**		TB2, RB1	239-296
		One dimensional unsteady heat conduction, lumped system analysis; use of Heisler chart, periodic changes of surface temperature.	https://cosmolearning.org/video-lectures/heat-conduction-vi/		
Assignment 2					
18-27		**Convection**		TB1, RB4	377-560
		Free and forced convection, hydrodynamic and thermal boundary layer equation over flat plate, laminar boundary layer analysis, fully developed heat transfer through smooth pipes, relation between fluid friction and heat transfer forced convection correlations, laminar free convection on a vertical flat plate, empirical co-relations, application of dimensional analysis.	https://cosmolearning.org/video-lectures/forced-convection-i/ https://cosmolearning.org/video-lectures/natural-convection-i/		
Assignment 3					
Mid-Semester Exam (Syllabus covered from 1-27 lectures)					
28-32		**Heat Exchanger**		TB1, RB1	647-670
		Types, LMTD, effectiveness, NTU method, single and multipass.	https://cosmolearning.org/video-lectures/heat-exchangers-i/		
33-38		**Radiation**		TB1, RB3	713-796
		Physical mechanism, radiation properties, black body radiation, grey body, kirchoff's law, Wien's displacement law, view factor, radiation exchange between infinite planes, radiation shields.	https://cosmolearning.org/video-lectures/thermal-radiation-i/		
39-42		**Mass Transfer**		TB2, RB3	833-870

		Fick's law, analogy between heat and mass transfer, equimolal counter diffusion, isothermal evaporation of water through stagnant air.	https://cosmolearning.org/video-lectures/introduction-to-mass-transfer-i/		
Assignment 4					

Evaluation Scheme:

Component 1	Mid Semester Exam	20
Component 2	Assignment Evaluation	10
Component 3**	End Term Examination**	70
	Total	**100**

** The End Term Comprehensive examination will be held at the end of semester. The mandatory requirement of 75% attendance in all theory classes is to be met for being eligible to appear in this component.

SYLLABUS

Topics	No of lectures	Weightage
Introduction : Basic concepts and modes of heat transfer	1	2%
Conduction: General three dimensional heat conduction equation; one dimensional steady heat conduction through composite plane walls; cylinders and spheres; critical radius of insulation.	6	14%
Extended Surface: Heat transfer from extended surfaces of uniform cross section.	4	10%
Unsteady Heat Transfer; One dimensional unsteady heat conduction, lumped system analysis; use of Heisler chart, periodic changes of surface temperature.	6	14%
Convection: Free and forced convection, hydrodynamic and thermal boundary layer equation over flat plate, laminar boundary layer analysis, fully developed heat transfer through smooth pipes, relation between fluid friction and heat transfer forced convection correlations, laminar free convection on a vertical flat plate, empirical co-relations, application of dimensional analysis.	10	24%
Heat Exchangers: Types, LMTD, effectiveness, NTU method, single and multipass.	5	12%

Radiation: Physical mechanism, radiation properties, black body radiation, grey body, kirchoff's law, Wien's displacement law, view factor, radiation exchange between infinite planes, radiation shields.	6	14%
Mass Transfer: Fick's law, analogy between heat and mass transfer, equimolal counter diffusion, isothermal evaporation of water through stagnant air.	4	10%

This Document is approved by:

Designation	Name	Signature
Course Coordinator	Madhav Ram	
H.O.D	Dr. Vishnu Singh	
Principal	Dr. Achintya	
Date		

Evaluation and Examination Blue Print:

Internal assessment is done through quiz tests, presentations, assignments and project work. Two sets of question papers are asked from each faculty and out of these two, without the knowledge of faculty, one question paper is chosen for the concerned examination. Examination rules and regulations are uploaded on the student's portal. Evaluation is a very transparent process and the answer sheets of sessional tests, internal assessment assignments are returned back to the students.

The components of evaluations along with their weightage followed by the University is given below

Mid semester exam	20%
Assignments/Quiz test /Seminars	10%
End term examination	70%

(From amongst the three sessional tests best of two are considered)

UNIT NO.	LECTUE NO.	Date	LECTURE TOPIC	LECTURE DETAILS	OUTCOMES
1	1.		Introduction	Heat, Heat Transfer, Difference between Thermodynamics and Heat Transfer subject, Application areas of Heat and Mass Transfer.	CO1
	2.		Heat Transfer Mechanisms	Three modes of heat transfer namely Conduction, Convection and Radiation with some real life examples.	CO1
	3.		Governing laws of heat transfer	Fourier law of heat conduction, Newton's law of cooling, Stefan Boltzmann law.	
	4.		Thermal Conductivity	Definition, Unit, Average value of thermal conductivity of some materials (solid, liquid, gases), Variation of thermal conductivity with temperature.	
2	5.		One dimensional heat conduction equation	One dimensional heat conduction equation in a large plane wall, long cylinder and sphere, Thermal diffusivity and its significance.	
	6.		Generalised three dimensional heat conduction equation	Derivation, Assumptions, Boundary conditions & Initial conditions for solving the heat conduction equation.	
	7.		Solution of steady one dimensional heat conduction problems	Problems related to heat conduction in large plane walls, cylinders and spheres with or without heat generation.	
	8.		Continued...	Problems (Temperature distribution within wall material, heat transfer rate through conduction), Variable thermal conductivity.	
	9.		Steady heat conduction	Thermal resistance concept, Thermal resistance value for plane wall, cylinder & sphere. Convection resistance, Radiation resistance.	
	10.		Generalized thermal	Multilayer plane walls, cylinders and	

			resistance networks	spheres. Numerical problems.	
	11.		Critical radius of insulation	Physical significance of critical radius, Thermal contact resistance, Numerical Problems.	
3	12.		Heat transfer from Extended Surfaces (Fins)	Advantages & Application of Fins, Fin analysis: Derivation of differential equation, Assumption, Boundary conditions for different cases.	
	13.		Temperature distribution & Heat transfer rate from the fin	Solution of differential equation (Fin of uniform cross section) for the different cases, 1. Infinite long fin, 2. Adiabatic fin tip, 3. Specified temperature at fin tip, 4. Convection from fin tip.	
	14.		Continued	Corrected fin length, Numerical Problems: calculation of temperature at any point within the fin & heat transfer rate from the fin surface.	
	15.		Fin efficiency & Fin effectiveness	Difference between fin efficiency and fin effectiveness, overall effectiveness, Factor consideration in the design and selection of the fins, Numerical Problems.	
4	16.		Unsteady (Transient) heat transfer	Lumped system analysis: Derivation of temperature variation with respect to time only.	
	17.		Criteria for lumped system analysis	Definition & significance of Biot No., Numerical Problems on lumped body : calculation of temperature or time and heat transfer rate.	
	18.		Transient heat conduction (Temperature variation with time & position in 1-D)	Transient heat conduction in large plane walls, long cylinders, and spheres with spatial effects. Fourier number.	
	19.		Continued..	Use of Heisler charts, Numerical problems.	
5	20.		Convection	Physical mechanism of convection,	

			(Introduction)	classification of fluid flows, velocity boundary layer, thermal boundary layer.	
	21.		Continued....	Laminar & turbulent flows, Reynolds number, Prandtl number, Nusselt number, Wall shear stress.	
	22.		Fluid flow equations	The continuity equation, Momentum equations, Energy equation, Solutions of convection equations for a flat plate.	
	23.		Continued..	Relation between fluid friction and heat transfer forced convection correlations: Stanton number, Reynolds analogy, Chilton-Colburn analogy, Numerical problems.	
	24.		External forced convection	Parallel flow over flat plates (Laminar & Turbulent flow): Boundary layer thickness, Local friction coefficient, Friction & Pressure Drag.	
	25.		Continued....	Local & Average Nusselt number. Flat plate with unheated starting length, uniform heat flux.	
	26.		Continued....	Flow across cylinder and spheres, Numerical problems (External forced convection).	
	27.		Internal forced convection	Fully developed heat transfer through smooth pipes, Development of the velocity boundary layer in a pipe, Velocity & Temperature profile in a pipe.	
	28.		Continued...	Nusselt number relation for constant surface heat flux & constant surface temperature, Numerical problems (Related to internal flow).	
	29.		Free (Natural) convection.	Physical mechanism of Natural convection, Equation of the motion, Grashof number.	
	30.		Natural convection over surfaces	Rayleigh number, Laminar free convection on a vertical flat plate,	

				Numerical problems on natural convection heat transfer.	
	31.		Dimensional Analysis	Introduction, Application of dimensional analysis, Problems.	
6	32.		Heat Exchangers	Types of Heat Exchangers, Application areas of Heat exchangers.	
	33.		Continued...	Shell & Tube Heat exchanger, Overall heat transfer coefficient, fouling factor.	
	34.		Heat exchanger analysis	Steady flow energy equation for the heat exchanger, calculation of heat transfer rate from hot fluid to cold fluid, appropriate mean temperature difference.	
	35.		LMTD (Log mean temperature difference)	LMTD expression for parallel flow & counter flow heat exchanger, Special cases in LMTD.	
	36.		Continued...	Multi pass and cross flow heat exchanger, correction factor, Numerical related to calculation of LMTD & heat transfer rate for different heat exchangers.	
	37.		Design of heat exchangers	LMTD Method : Procedure, Numerical problems (calculation of heat transfer surface area, no. of tubes, no. Of passes required)	
	38.		Continued...	ε-NTU method: NTU, effectiveness, capacity ratio, procedure, Numerical problems (calculation of exit temperature of cold fluid & hot fluid).	
7	39.		Radiation	Introduction, Thermal Radiation, Black body radiation, Stefan-Boltzmann law.	
	40.		Continued...`	Spectral black body emissive power, Wien’s displacement law, Radiation intensity, solid angle.	
	41.		Radiation properties	Emissivity, Absorptivity, Reflectivity, Transmissivity, Spectral quantities,	

				Radiosity, Kirchhoff’s law.	
	42.		Radiation heat transfer	View factor, View factor relations: Reciprocity relation, Summation rule, Superposition rule, Symmetry rule, Numerical problems (calculation of view factor).	
	43.		Continued...	Diffuse & Gray surfaces, Net radiation heat transfer between two black surfaces, Net radiation heat transfer to or from a surface.	
	44.		Continued...	Radiation heat transfer in two-surface enclosures & three-surface enclosures, radiation networks, radiation shields, Numerical problems.	
8	45.		Mass Transfer	Introduction, Analogy between Heat and Mass transfer: Temperature, conduction, Heat generation, Convection.	
	46.		Continued...	Mass diffusion: Mass basis, Mole basis, Fick’s law of diffusion, Boundary conditions,	
	47.		Continued...	Steady mass diffusion through a wall, Diffusion resistance, Equimolal counter diffusion.	
	48.		Continued...	Isothermal evaporation of water through stagnant air, Numerical problems (calculation of mass flow rate of diffusion).	

DARBHANGA COLLEGE OF ENGINEERING

DARBHANGA, BIHAR

Department of Mechanical Engineering

Heat and Mass Transfer

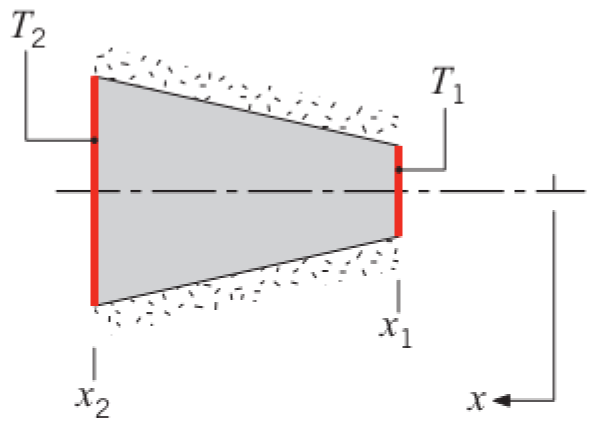
Assignment I

1. Consider a large plane wall of thickness L = 0.2 m, thermal conductivity k = 1.2 W/m.°C, and surface area A = 15 m^2. The left and right sides of the wall are maintained at constant temperatures of T_1 = 120°C and T_2 = 50°C, respectively. Determine (a) the variation of temperature within the wall and the value of temperature at x = 0.1 m and (b) the rate of heat conduction through the wall under steady conditions.

2. The diagram shows a conical section fabricated from pyroceram. It is of circular cross section with the diameter D = ax, where a = 0.25. The small end is at x_1 = 50 mm and the large end at x_2 = 250 mm. The end temperatures are T_1 = 400 K and T_2 = 600 K, while the lateral surface is well insulated.

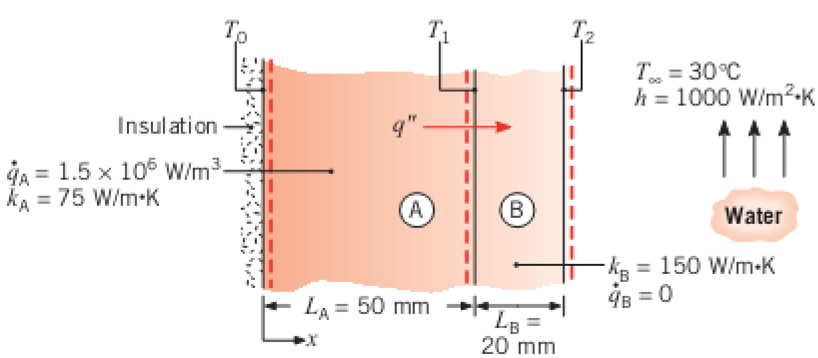
1.Derive an expression for the temperature distribution T(x) in symbolic form, assuming one-dimensional conditions. Sketch the temperature distribution.

2.Calculate the heat rate q_x through the cone.

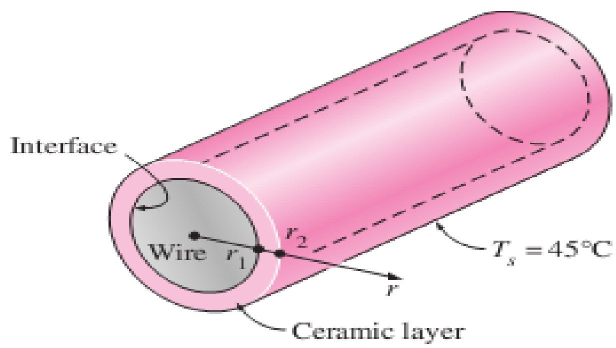


3. A plane wall is a composite of two materials, A and B. The wall of material A has uniform heat generation $q = 1.5 \times 10^6$ W/m^3 , $k_A = 75$ W/m.K, and thickness $L_A = 50$ mm. The wall material B has no generation with $k_B = 150$ W/m.K and thickness $L_B = 20$ mm. The inner surface of material A is well insulated, while the outer surface of material B is cooled by a water stream with $T_\infty = 30°C$ and $h = 1000$ W/m^2.K.

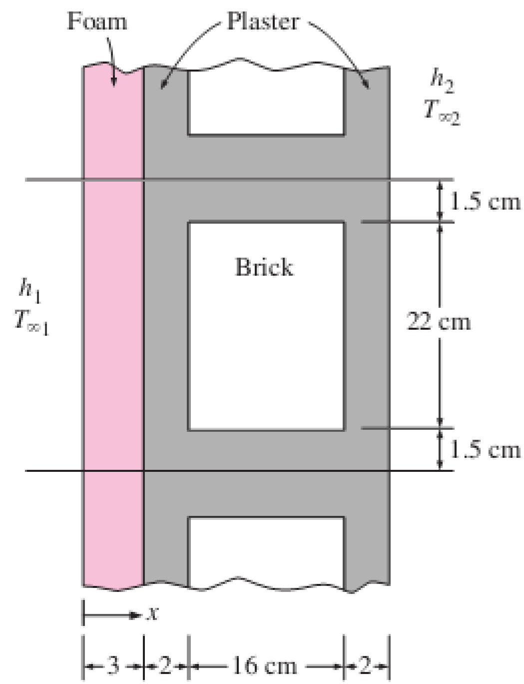
   1. Sketch the temperature distribution that exists in the composite under steady-state conditions.
   2. Determine the temperature T_0 of the insulated surface and the temperature T_2 of the cooled surface.



4. Consider a long resistance wire of radius r_1 = 0.2 cm and thermal conductivity k_{wire} = 15 W/m°C in which heat is generated uniformly as a result of resistance heating at a constant rate of e_{gen} = 50 W/cm^3. The wire is embedded in a 0.5-cm-thick layer of ceramic whose thermal conductivity is $k_{ceramic}$ = 1.2 W/m°C. If the outer surface temperature of the ceramic layer is measured to be T_s = 45°C, determine the temperatures at the center of the resistance wire and the interface of the wire and the ceramic layer under steady conditions.



5. A 3-m-high and 5-m-wide wall consists of long 16-cm × 22-cm cross section horizontal bricks (k = 0.72 W/m.°C) separated by 3-cm-thick plaster layers (k = 0.22 W/m.°C). There are also 2-cm-thick plaster layers on each side of the brick and a 3-cm-thick rigid foam (k = 0.026 W/m.°C) on the inner side of the wall, as shown in Figure below. The indoor and the outdoor temperatures are 20°C and 10°C, and the convection heat transfer coefficients on the inner and the outer sides are h_1 = 10 W/m^2.°C and h_2 = 25 W/m^2.°C, respectively. Assuming one-dimensional heat transfer and disregarding radiation, determine the rate of heat transfer through the wall.



6. A 3-mm-diameter and 5-m-long electric wire is tightly wrapped with a 2-mm-thick plastic cover whose thermal conductivity is k = 0.15 W/m.°C. Electrical measurements indicate that a current of 10 A passes through the wire and there is a voltage drop of 8 V along the wire. If the insulated wire is exposed to a medium at T_∞ = 30°C with a heat transfer coefficient of h = 12 W/m^2.°C, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also determine whether doubling the thickness of the plastic cover will increase or decrease this interface temperature.

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Assignment II

7. A very long rod 5 mm in diameter has one end maintained at 100 °C. The surface of the rod is exposed to ambient air at 25°C with a convection heat transfer coefficient of 100 $W/m^2.°C$.

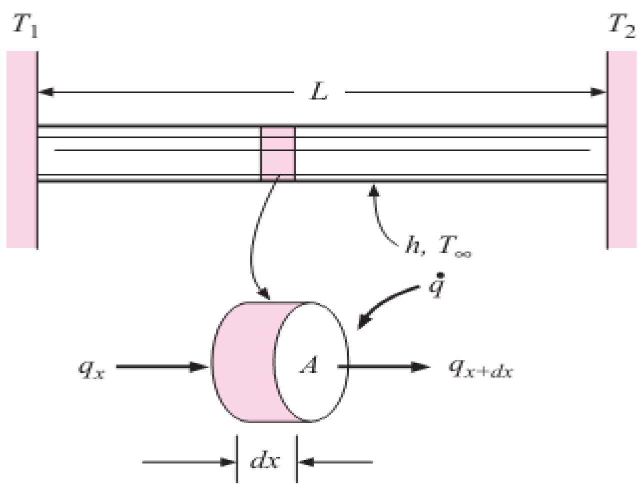
1. Determine the temperature distributions along rods constructed from pure copper, 2024 aluminum alloy, and type AISI 316 stainless steel. What are the corresponding heat losses from the rods?
2. Estimate how long the rods must be for the assumption of infinite length to yield an accurate estimate of the heat loss.

2. The engine cylinder of a motorcycle is constructed of 2024-T6 aluminum alloy and is of height $H = 0.15$ m and outside diameter $D = 50$ mm. Under typical operating conditions the outer surface of the cylinder is at a temperature of 500 K and is exposed to ambient air at 300 K, with a convection coefficient of 50 $W/m^{2}\cdot K$. Annular fins are integrally cast with the cylinder to increase heat transfer to the surroundings. Consider five such fins, which are of thickness $t = 6$ mm, length $L = 20$ mm, and equally spaced. What is the increase in heat transfer due to use of the fins?

3. A thermocouple junction, which may be approximated as a sphere, is to be used for temperature measurement in a gas stream. The convection coefficient between the junction surface and the gas is $h = 400$ W/m^2K, and the junction thermo-physical properties are $k = 20$ W/m.K, c =400 J/kg.K, and $\rho = 8500$ kg/m3. Determine the junction diameter needed for the thermocouple to have a time constant of 1 s. If the junction is at 25°C and is placed in a gas stream that is at 200 °C, how long will it take for the junction to reach 199°C?

4. A person is found dead at 5 PM in a room whose temperature is 20°C. The temperature of the body is measured to be 25°C when found, and the heat transfer coefficient is estimated to be h = 8 W/m^2.°C. Modeling the body as a 30-cm-diameter, 1.70-m-long cylinder, estimate the time of death of that person.

5. A rod containing uniform heat sources per unit volume q is connected to two temperatures as shown in Figure below. The rod is also exposed to an environment with convection coefficient h and temperature T_∞. Obtain an expression for the temperature distribution in the rod.



6. A long 20-cm-diameter cylindrical shaft made of stainless steel 304 comes out of an oven at a uniform temperature of 600°C. The shaft is then al-lowed to cool slowly in an environment chamber at 200°C with an average heat transfer coefficient of h = 80 W/m^2.°C. Determine the temperature at the center of the shaft 45 min after the start of the cooling process. Also, determine the heat transfer per unit length of the shaft during this time period.

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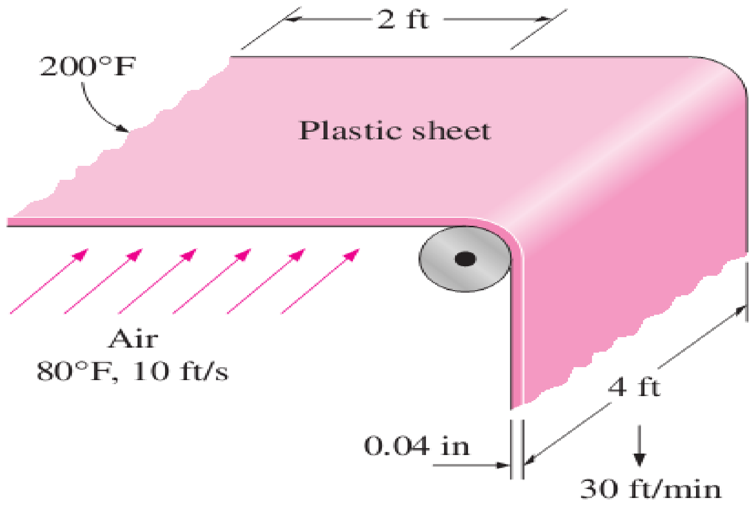
Assignment III

1. Air at a pressure of 6 kN/m^2 and a temperature of 300°C flows with a velocity of 10 m/s over a flat plate 0.5 m long. Estimate the cooling rate per unit width of the plate needed to maintain it at a surface temperature of 27°C.

2. The forming section of a plastics plant puts out a continuous sheet of plastic that is 4 ft wide and 0.04 in. thick at a velocity of 30 ft/min. The temperature of the plastic sheet is 200°F when it is exposed to the surrounding air, and a 2-ft-long section of the plastic sheet is subjected to air flow at 80°F at a velocity of 10 ft/s on both sides along its surfaces normal to the direction of motion of the sheet, as shown in Figure below.

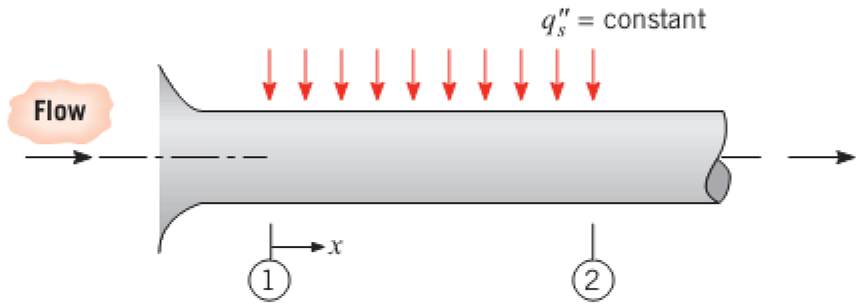
   Determine (a) the rate of heat transfer from the plastic sheet to air by forced convection and radiation and (b) the temperature of the plastic sheet at the end of the cooling section. Take the density, specific heat, and emissivity of the plastic sheet to be $\rho = 75$ lbm/ft^3, $C_p = 0.4$ Btu/lbm ·°F, and $\varepsilon = 0.9$.



3. A square (10 mm × 10 mm) silicon chip is insulated on one side and cooled on the opposite side by atmospheric air in parallel flow at $u_\infty = 20$ m/s and $T_\infty = 24$ °C. When in use, electrical power dissipation within the chip maintains a uniform heat flux at the cooled surface. If the chip temperature may not exceed 80°C at any point on its surface, what is the maximum allow-able power? What is the maximum allowable power if the chip is flush mounted in a substrate that provides for an unheated starting length of 20 mm?

4. Steam condensing on the outer surface of a thin-walled circular tube of diameter D = 50 mm and length L = 6 m maintains a uniform outer surface temperature of 100°C. Water flows through the tube at a rate of m = 0.25 kg/s, and its inlet and outlet temperatures are $T_{m,i}$ = 15°C and $T_{m,o}$ = 57°C. What is the average convection coefficient associated with the water flow?

5. Consider flow in a circular tube. Within the test section length (between 1 and 2) a constant heat flux q_s'' is maintained.



a. For the following two cases, sketch the surface temperature $T_s(x)$ and the fluid mean temperature $T_m(x)$ as a function of distance along the test section x. In case A, flow is hydro-dynamically and thermally fully developed. In case B, flow is not developed.

b. Assuming that the surface flux q_s'' and the inlet mean temperature $T_{m,1}$ are identical for both cases, will the exit mean temperature $T_{m,2}$ for case A be greater than, equal to, or less than $T_{m,2}$ for case B? Briefly explain why ?

6. Hot air at atmospheric pressure and 80°C enters an 8–m-long un-insulated square duct of cross section 0.2 m × 0.2 m that passes through the attic of a house at a rate of 0.15 m^3/s. The duct is observed to be nearly isothermal at 60°C. Determine the exit temperature of the air and the rate of heat loss from the duct to the attic space.

7. Consider a 0.6m × 0.6m thin square plate in a room at 30˚C. One side of the plate is maintained at a temperature of 90˚C, while the other side is insulated. Determine the rate of heat transfer from the plate by natural convection if the plate is (a) vertical, (b) horizontal with hot surface facing up, and (c) horizontal with hot surface facing down.