COURSE CONTENT

HEAT TRANSFER LABORATORY								
VI Semester: ME								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
AMEC36	Foundation	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		-	0	3	1.5	30	70	100
Contact Classes: Nil	**Tutorial Classes: Nil**	**Practical Classes:45**				**Total Classes:45**		
Prerequisite: Applied Thermodynamics Laboratory								

I. COURSE OVERVIEW:

Heat transfer laboratory is intended to enhance the learning experience of the student about the flow of thermal energy due to temperature difference and the subsequent temperature distribution changes. This laboratory focuses on heat transfer modes, boundary conditions, one dimensional steady and unsteady state condition and heat exchangers applied to modern electric and electronic plants require efficient dissipation of thermal losses. Students are expected to gain experience in hands on training as well as knowledge to model heat exchangers, heat treatment of fins and complex mechanical systems.

II. COURSES OBJECTIVES:

The students will try to learn

I	The design calculations of different modes of heat transfer to improve the efficiency of heat transfer rate and thermal conductivity with different materials.
II	The validating heat transfer parameters during internal and external flows based on non-dimensional numbers with convective mode heat transfer.
III	The performance and analysis of heat exchangers for real-time applications using logarithmic mean temperature difference and number of transfer unit methods.

III. COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	Demonstrate the steps involved with different surfaces and geometries for which the temperature distribution and heat flow rates are calculated for automotive industry components like radiators, engine blocks.
CO 2	Execute the principles associated with convective heat transfer to formulate and calculate the dynamics of temperature field in fluid flow for real time applications.
CO 3	Determine the surface heat transfer coefficient in natural convection of heated vertical cylinder for forced convection in a drop wise and film wise condensation.
CO 4	Make use of the phenomena of boiling and condensation to give various correlations applied to heat exchangers, boilers and heat engines.
CO 5	Select the appropriate expression in overall heat transfer coefficient for modelling heat exchanger to achieve defect / error free components.
CO 6	Apply the lumped heat capacity method in unsteady heat transfer process to study the rates of heat transfer for different materials and geometries.

IV. COURSE CONTENT

EXERCISES ON HEAT TRANSFER LABORATORY

Safety

Safety is a vital issue in all workplaces. Before using any equipment and machines or attempt practical work in a laboratory everyone must understand basic safety rules. These rules will help keep all safe in the laboratory.

Safety Rules

1. Always listen carefully to the teacher and follow instructions.
2. When learning how to use a machine, listen very carefully to all the instructions given by the faculty / instructor. Ask questions, especially if you do not fully understand.
3. Always wear an apron as it will protect your clothes and holds lose clothing such as ties in place.
4. Wear good strong shoes.
5. Bags should not be brought into a workshop as people can trip over them.
6. Do not use a machine if you have not been shown how to operate it safely by the faculty / instructors
7. Know where the emergency stop buttons are positioned in the laboratory. If you see an accident at the other side of the workshop you can use the emergency stop button to turn off all electrical power to machines.
8. Always be patient, never rush in the laboratory.
9. Always use a guard when working on a machine.
10. Keep hands away from moving/rotating machinery.
11. Use hand tools carefully, keeping both hands behind the cutting edge.
12. Report any UNSAFE condition or acts to instructor.
13. Report any damage to machines/equipment as this could cause an accident.
14. Keep your work area clean.

1. Getting Started Exercises

Introduction

The objective of this lab is to understand the concepts of conduction, convection and radiation practically in various thermal systems to under graduate students through a series of experiments. Students have a good understanding of the theory underlying the experiments and the entire lab course is designed such that classroom lectures precede the lab work. The Heat Transfer Laboratory is equipped with test facilities for doing research with in internal combustion engines for energy conversion.

1.1 Find the thermal conductivity and temperature distribution of cylindrical composite wall.

It is the transport of energy between two or more bodies of different thermal conductivity arranged in series or parallel. Hence, the thermal conductivity of the fastener is also very much necessary in determining the overall heat transfer through the medium.

Hints

- By adjusting the dimmer knob give heat input to heater. (Say 60V) from figure 1.1.
- Wait for about 20 -30 min. approximately to reach the steady state condition.
- Take the readings of all (8) the thermocouples.
- Tabulate the readings in observation table for calculating the thermal conductivity.

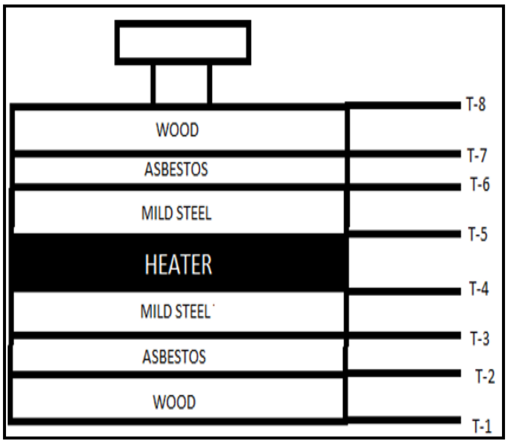

Figure 1.1 composite wall

1.2 Determine the overall thermal conductance for a composite wall and compare with theoretical value.

When a temperature gradient exists in a body, there is an energy transfer from the high temperature region to the low temperature region. Energy is transferred by conduction and heat transfer rate per unit area is proportional to the normal temperature gradient.

Try

1. Determination of thermal conductivity with copper, aluminium, and brass composite wall.
2. Determination of temperature distribution across the width of the composite wall.

2. Thermal conductivity of Insulating material

The apparatus consists of three concentric pipes mounted on suitable stand. The hollow space of the innermost pipe consists of the heater. Between first two cylinders the insulating material with which lagging is to be done is filled compactly.

2.1 Find the thermal conductivity of insulating materials through lagged pipe.

Hints:

i) Switch on the heater using the regulator and keep the power input at some particular value from figure 2.1.

ii) Allow the unit to stabilize for about 20 to 30 minutes

iii) Now note down the ammeter reading, voltmeter reading, which gives the heat input, and the average temperature of each cylinder is taken for calculation.

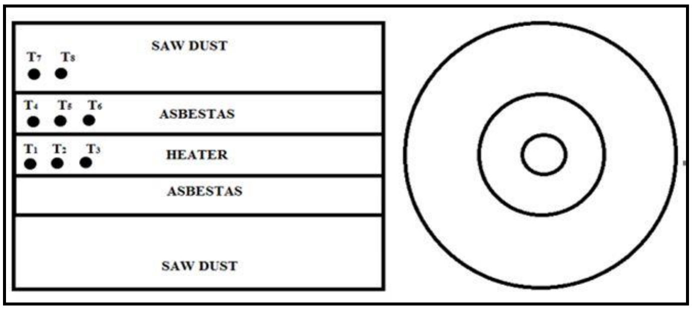

Figure 2.1 Lagged pipe apparatus

2.2 Determine combined convective and radiation heat transfer coefficient at each zone and compare them to decide the critical thickness of insulation.

Thermal conductivity is basically the property of a material that allows the flow of heat through the material. It is also known as the coefficient of conductivity, because it is given as a number that can be used in equations. The thermal conductivity of any particular material, it indicates how well it allows heat to flow.

Try

1. Thermal Conductivity of Insulation materials at different mean temperatures.
2. Determination of thermal conductivity by lagged pipe apparatus.

3. Thermal conductivity of insulating powder at various heat inputs

Thermal conductivity is the physical property of material denoting the ease with a particular substance can accomplish the transmission of thermal energy by molecular motion.

3.1 Find the thermal conductivity of insulating powder.

Hints:

i) The apparatus consists of two concentric copper spheres and Heating coils is provided in the inner sphere from figure 3.1.
ii) The space between the inner and outer spheres are filled by the insulating powder whose thermal conductivity is to be determined.
iii) The power supply to the heating coils is adjusted by using dimmer stat.
iv) Chromel - Alumel thermocouples are used to record the temperatures.

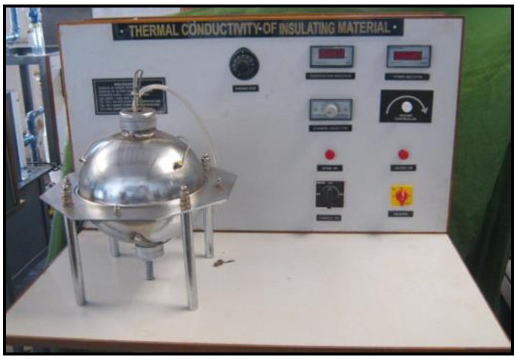

Figure. 3.1 Concentric sphere

3.2 Determine the thermal conductivity of given concentric sphere

Thermal conductivity of a material is found, to depend on the chemical composition of the substances of which it is a composed, the phase (i.e. gas, liquid or solid) in which its crystalline structure if a solid, the temperature & pressure to which it is subjected and whether or not it is homogeneous material.

Try

1. Experimental Study of heat transfer between concentric spheres.
2. Determine the thermal conductivity of given concentric sphere from figure 3.1.

4. Thermal conductivity of brass rod

The apparatus consists of a brass rod, one end of which is heated by an electric heating coil while the other end projects into the cooling water jacket. The rod is insulated with glass wool to minimize the radiation and convection loss from the surface of the rod and thus ensure nearly constant temperature gradient throughout the length of the rod.

4.1 Find the thermal conductivity and temperature distribution of the brass rod.

Hints:

1) The temperature of the rod is measured at five different locations. The heater is provided with a dimmer stat for controlling the heat input.
2) Water is circulated through the jacket and its flow rate and temperature rise can be measured.

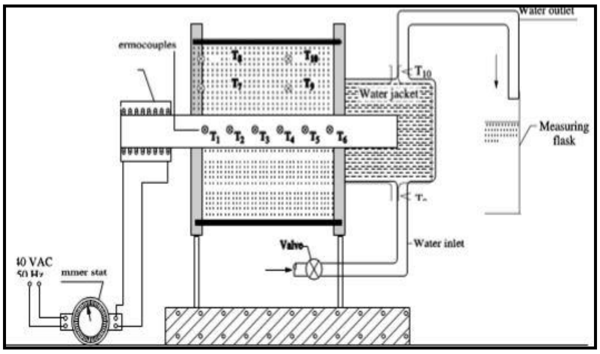

Figure 4.1 Experimental setup

4.2 Measure the temperature gradient along the length of the metal (copper) rod

Conduction is a process of heat transfer through solids. When a temperature gradient exists in a body, experience has shown that there is a transfer of heat from the high temperature region to the low temperature region.

Try

1. Determine the thermal conductivity of different materials rods as shown in the Figure 4.1.
2. To determine the co-efficient of thermal conductivity of the metal.

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5. Heat transfer through pin-fin

A fin of brass (iron or copper) of circular cross-section (square or triangular) or length L is fitted in rectangular duct. One end of the fin which is projected outside duct is provided with a heater for heating the fin.

5.1 Find the rate of heat transfer through pin-fin apparatus.
Hints:

i) A pin fin is screwed to a cylindrical heating pipe making the test section from figure 5.1.
ii) The test section is kept in a rectangular duct, which is open of both ends for natural air flow.
iii) Five thermocouples are embedded on pin fin at intervals of 25mm.

5.2 Determine the rate of heat transfer of circular pin-fin

Connect the equipment to electric power supply and keep the thermocouple selector switch to zero position. Turn the dimmer stat clockwise and adjust the power input to the heater to the desired value and switch on the blower.

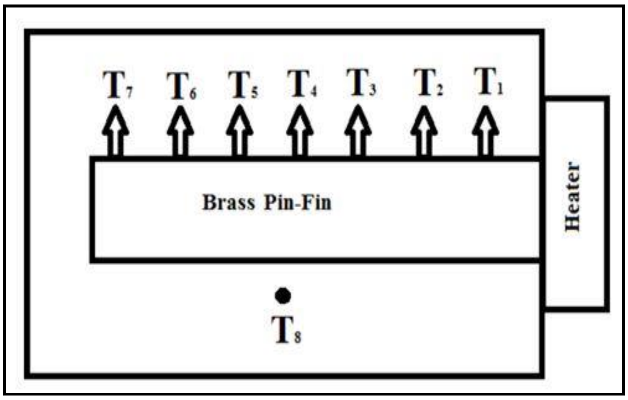

Figure 5.1. Brass pin - Fin Apparatus

Try

1. Prepare the pin – Fin apparatus for iron or copper to determine rate of heat transfer.
2. To find out the temperature distribution along the given fin for constant base temperature under natural and force flow conditions.
3. To find out effectiveness of the fin under both conditions.

6. Transient heat conduction

Unsteady state designates a phenomenon which is time dependent. Conduction of heat in unsteady state refers to transient conditions where in, heat flow and temperature distribution at any point of system varies with time.

6.1 Obtain the specimen temperature at any interval of time transient heat conduction apparatus.
Hints:

i) Unsteady state heat transfer equipment has water check which is at top of water heater as shown in figure 6.1.
ii) Thermocouple No.1 is located inside the specimen
iii) No. 2 thermocouple measures the atmospheric temperature.
iv) No.3 thermocouple measures the oil temperature.

Figure 6.1. Transient Heat Conduction Apparatus

6.2 Determine the thermal conductivity of a solids and the heat transfer coefficient.

Unsteady state designates a phenomenon which is time dependent. Conduction of heat in unsteady state refers to transient conditions where in, heat flow and temperature distribution at any point of system varies with time.

Try

1. Transient Heat Conduction of aluminum specimen.
2. To determine heat transfer coefficient and instantaneous heat transfer rate for transient heat conduction and draw the graph of temperature variation with time.

7. Heat transfer through pin-fin forced convection.

A fin of brass of circular cross-section (square or triangular) or length L is fitted in rectangular duct. One end of the fin which is projected outside duct is provided with a heater for heating the fin. Five thermocouples are provided on the surface of the fin at equal distances.

7.1 Determine the rate of heat transfer through pin-fin forced convection.

Hints:

- Connect the equipment to electric power supply and keep the thermocouple selector switch to zero position as shown in figure 7.1.
- Turn the dimmer stat clockwise and adjust the power input to the heater to the desired value and switch on the blower
- Set the air–flow rate to any desired value by adjusting the difference in water levels in the manometer and allow the unit to stabilize.

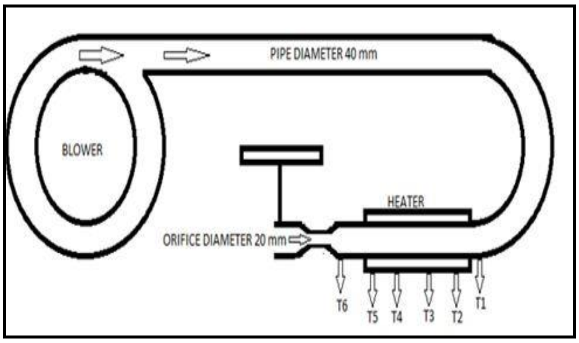

Figure 7.1 Forced convection Apparatus

7.2 Find the temperature distribution along the given fin for constant base temperature under natural and force flow conditions.

A fin of brass of circular cross-section (square or triangular) or length L is fitted in rectangular duct. One end of the fin which is projected outside duct is provided with a heater for heating the fin. Five thermocouples are provided on the surface of the fin at equal distances.

Try

1. Prepare the pin – Fin apparatus for copper to determine rate of heat transfer by forced convection.
2. To find out effectiveness of the fin under both conditions.

8. Heat transfer with natural convection

Natural convection heat transfer takes place by movement of fluid particles on solid surface caused by density difference between the fluid particles on account of difference in temperature. Hence there is no external agency facing fluid over the surface.

8.1 Determine the rate of heat transfer with natural convection

Hints:

i) The apparatus consists of a stainless-steel tube fitted in a rectangular duct in a vertical position as shown in figure 8.1.
ii) The duct is open at the top and bottom and forms an enclosure and serves the purpose of undisturbed surroundings.
iii) One side of the duct is made of acrylic sheet for visualization.

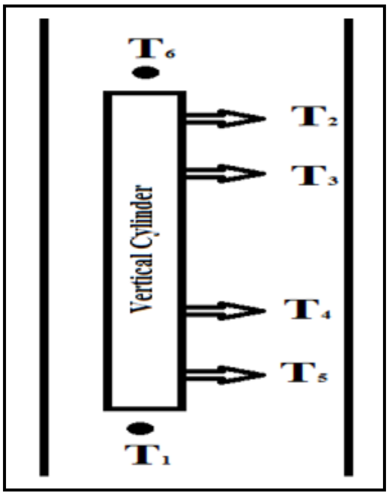

Figure 8.1 Natural heat conduction apparatus

8.2 Determine the rate of heat transfer with natural convection

The fins are commonly used on engine heads of scooter, motorcycles, as well as small capacity compressors. The pin type fins are also used on the condenser of a domestic refrigerator.

Try

1. Find out heat transfer coefficient and heat transfer rate from vertical cylinder in natural convection at different rate of heat transfer.
2. To study the temperature distribution along the length of a pin under free convection heat transfer.

9. Heat transfer coefficient for counter flow heat exchanger

Heat Exchangers are devices in which heat is transferred from one fluid to another. The necessity for doing this arises in a multitude of industrial applications. Common examples of heat exchangers are the radiator of a car, the condenser at the back of a domestic refrigerator and the steam boiler of a thermal power plant.

9.1 Determine LMTD, effectiveness and overall heat transfer coefficient for counter flow heat exchanger.

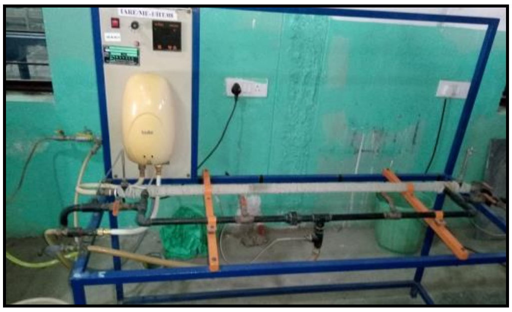

Figure 9.1 Parallel flow heat exchanger

9.2 Determine LMTD & Effectiveness of the heat exchanger under parallel and counter Flow arrangement.

The apparatus consists of a tube in tube type concentric tube heat exchanger. The hot fluid is hot water which is obtained from an insulated water bath using a magnetic drive pump and it flows through the inner tube while the cold fluid is cold water flowing through the annulus.

Try

1. Determine LMTD, effectiveness and overall heat transfer coefficient for parallel flow heat exchanger as shown in figure 9.1.
2. Find out the temperature distribution along the given fin for constant base temperature under natural and force flow conditions.
3. Find out effectiveness of the fin under both conditions.

10. Emissivity measurement of radiating surfaces

Any hot body maintained by a constant heat source, loses heat to surroundings by conduction, convection and radiation. If two bodies made of same geometry are heated under identical conditions, the heat loss by conduction and convection can be assumed same for both the bodies, when the difference in temperatures between these two bodies is not high.

10.1 Determine the emissivity measurement of radiating surfaces with grey body.

Figure 10.1 emissivity measurement

10.2 Measure the emissivity of the gray body (plate) at different temperature and plot the variation of emissivity with surface temperature.

Radiation is one of the modes of heat transfer, which does not require any material medium for its propagation. All bodies can emit radiation & have also the capacity to absorb all or a part of the radiation coming from the surrounding towards it.

Try

1. Determine the emissivity measurement of radiating surfaces at different temperature of black body from figure 10.1.
2. Determine the emissivity of the non – black surface and compare with the black body.

11. Stefan Boltzmann constant for radiation heat transfer

Stefan Boltzmann law states that the total emissive power of a perfect black body is proportional to fourth power of the absolute temperature of black body surface. The apparatus consists of a flanged copper hemisphere fixed on a flat non- conducting plate.

11.1 Determine the value of Stefan Boltzmann constant for radiation heat transfer.

Hints:

- The disc is mounted on an ebonite rod which is fitted in a hole drilled at the center of the base plate.
- Another Cr-Al thermocouple is fixed to the disc to record its temperature.

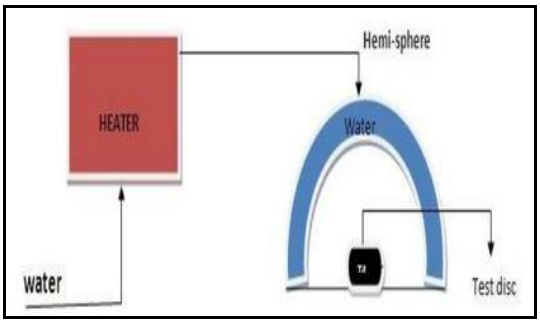

Figure 11.1 Stefan Boltzmann Apparatus

11.2 Determine the value of Stefan Boltzmann constant for radiation heat transfer

Stefan Boltzmann law states that the total emissive power of a perfect black body is proportional to fourth power of the absolute temperature of black body surface. The apparatus consists of a flanged copper hemisphere fixed on a flat non- conducting plate.

Try

1. Determine the value of Stefan Boltzmann constant for radiation heat transfer at different heat transfer rates from figure 11.1.
2. Determine the value of Stefan Boltzmann constant for radiation heat transfer by changing hemisphere material.

12. Critical heat flux

When heat is added to a liquid surface from a submerged solid surface which is at a temperature higher than the saturation temperature of the liquid, it is usual that a part of the liquid to change phase.

12.1 Draw the graph of heat flux with bulk temperature up-to burnout (critical) condition.

Hints:

- An ammeter is connected in series to the current while a voltmeter across it to read the voltage.
- The glass container is kept on the table.
- The test heater wire can be viewed through a magnifying lens.

Figure 12.1 Critical heat flux Apparatus

12.2 Determine the phenomenon of the boiling heat transfer and observe the formation of pool boiling

The ability to predict critical heat flux (CHF) is of paramount importance to the safety of devices and systems involving boiling along heat-flux-controlled surfaces. Exceeding CHF amounts to catastrophic failure due to overheating or physical burnout. There are several methods to increasing CHF in order to broaden the permissible range of wall heat flux.

Try

1. Study the phenomenon of the boiling heat transfer at different test heaters from figure 12.1.
2. Experimental and theoretical study of critical heat flux in vertical up-flow with inlet vapor void.

13. Axial heat flux in a heat pipe

One of the main objectives of energy conversion systems is to transfer energy from a receiver to some other location where it can be used to heat a working fluid. The heat pipe is a novel device that can transfer large quantities of heat through small surface areas with small temperature differences.

13.1 Determine the axial heat flux in a heat pipe using water as the working fluid with that of a solid copper with different temperatures.

Hints:

- Switch on the heater and set the voltage (say 40V) using heater regulator and the digital voltmeter.
- Wait for sufficient time to allow temperature to reach steady values.

- Note down the Temperatures 1 to 6 using the channel selector and digital temperature indicator.

Figure 13.1 Heat Pipe Apparatus

13.2 Calculate & compare effectiveness of heat pipe & other good thermal conductor pipes.

The apparatus consists of a Solid Copper Rod of diameter (d) 25mm and length (L) 500mm with a source at one end and condenser at other end. Similarly, Hollow copper pipe without wick and with wick (SS mesh of 180microns) with same outer diameter and length is provided.

Try

1. Determine the axial heat flux in a heat pipe using water as the working fluid with that of a solid aluminum with different temperatures from figure 13.1.
2. Determine thermal conductivity of heat pipe.

14. Film and Drop Wise Condensation

Condensation is the process of change of state free vapour to liquid. Condensation occurs on a surface when the vapour saturation temperature is higher than the temperature of surface.

14.1 Determine overall heat transfer coefficient Film and Drop Wise Condensation Apparatus

Hints:

- Fill water slowly into the water tank and steam generator.
- Switch on the supply mains and console.
- Switch on the heater of steam generator to generate the steam.
- Open the inlet valve and allow the cold fluid to flow through the condenser.

Figure 14.1 Film and Drop Wise Condensation

14.2 Determine overall heat transfer coefficient Film and Drop Wise Condensation Apparatus

Condensation is the process of change of state free vapour to liquid. Condensation occurs on a surface when the vapour saturation temperature is higher than the temperature of surface. The temperature of the condensate so formed will be less than the saturation temperature of the vapour and becomes sub-cooled.

Try

1. Determine steam side film coefficient from figure 14.1.
2. Determine overall heat transfer coefficient.
3. Determine cold fluid heat transfer coefficient

V. TEXT BOOKS:

1. Yunus A. Cengel, "Heat Transfer a Practical Approach", Tata McGraw hill Education (P) Ltd, New Delhi, India. 4th edition, 2012.
2. R. C. Sachdeva, "Fundamentals of Engineering, Heat and Mass Transfer", New Age, New Delhi, India, 3rd edition, 2012.

VI. REFERENCE BOOKS:

1. Holman, "Heat Transfer", Tata McGraw-Hill education, 10th edition, 2011.
2. P. S. Ghoshdastidar, "Heat Transfer", Oxford University Press, 2nd edition, 2012.

VII. ELECTRONICS RESOURCES:

1. https://elearn.nptel.ac.in/shop/iit-workshops/ongoing/heat transfer-for-practicing-engineers/.
2. https://akanksha.iare.ac.in/index?route=course/details&course_id=94.

VIII. MATERIALS ONLINE:

1. Course Template
2. Lab manual