期末考试试卷

Final Examination Paper

2021-2022 学年第 2 学期

Spring Semester of 2021-2022 Academic Year

Heat Transfer

班　级 **Class :** ______________________

学　号 **Student No. :** ______________________

姓　名 **Name :** ______________________

成　绩 **Score :** ______________________

29 June 2022

北京航空航天大学国际通用工程学院

School of General Engineering, Beihang University

班号 Class Number ____________ 学号 Student Number ____________

中文姓名 Name ____________ 姓名拼音 Name Spelling ____________

题目 Number	I	II	III	IV	V	VI					
成绩 Score											
题目 Number	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	最终成绩 Total Score
成绩 Score											

INSTRUCTIONS

1. This examination paper contains 2 sections. The marks for each question are indicated at the beginning of each question.

2. Section A – Compulsory: Short answer questions

- 6 questions (30 points total)

Section B – Choose any 7 out of 10 questions

- 10 points each (70 points total)

Section A – Compulsory: Short answer questions (30 points in total)

I. (4pts) Please briefly explain **the relationship between thermodynamics and heat transfer**.

II. (4pts) If we touch a piece of steel and wood on a winter day, we feel that the steel is colder than wood. If we touch the steel and the wood on summer day, we feel that steel is hotter than wood. **Why**?

III. (4pts) Please write down the definition of **Reynolds number, Nusselt number, Prandtl number and Biot number**, then explain their **physical meanings**.

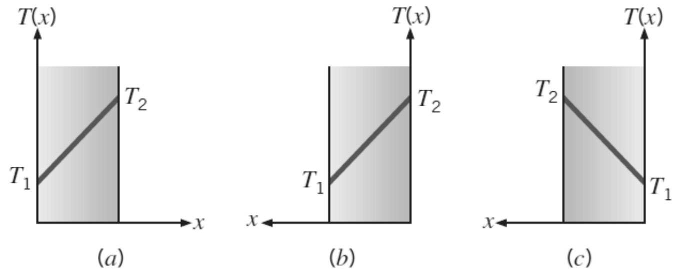
IV. (6pts) China will aim to hit peak carbon emissions before 2030 and for carbon neutrality by 2060, President Xi has announced. The announcement is being seen as a significant step in the fight against climate change. Please apply your knowledge about heat transfer to explain **how do greenhouse gases contribute to climate change**?

V. (6pts) China's Crewed Shenzhou 14 Spacecraft, atop a Long March-2F carrier rocket, is launched from the Jiuquan Satellite Launch Centre in northwest China on Sunday, June 5th, 2022. The spacecraft docked with the Tiangong space station late Sunday afternoon, the start of a six-month mission for three astronauts to oversee the final stages of the space station's construction. Please apply your heat transfer knowledge to explain **why do spacecraft need Thermal Control?**

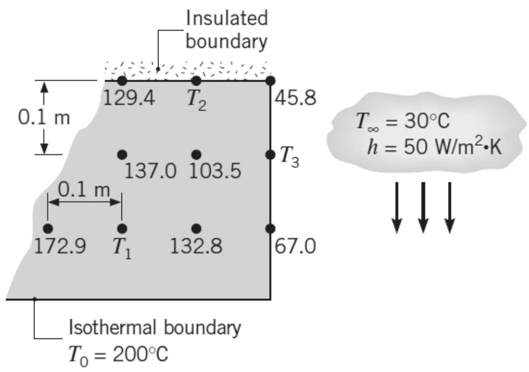
VI. (6pts) The robots are such a structure that consists of numerous different electronic components and devices. Such electronic parts have an operating temperature that directly effects the performance of robots. Therefore, thermal management systems should be designed carefully to meet the ideal working temperature of each component in the robot. Please boost your creativity to **propose a thermal management solution of lunar robots to operate in harsh environments on the Moon for Lunar Exploration.** (Hint: The environment of extreme temperatures, vacuum, radiation and dust. The average temperature on the Moon varies from -183 degrees Celsius at night, to 106 degrees Celsius during the day.)

<u>Section B</u> – Choose any 7 out of 10 questions below (10 points each)

VII. (10pts) Consider a plane wall 100mm thick and of thermal conductivity 100W/m·K. Steady-state conditions are known to exist with T_1=400K and T_2=600K. Determine the heat flux q_x'' and the temperature gradient dT/dx for the coordinate systems shown.



VIII. (10pts) The steady-state temperatures (°C) associated with selected nodal points of a two-dimensional system having a thermal conductivity of 1.5 W/m K are shown on the accompanying grid. Determine the temperatures at nodes 1, 2, 3.



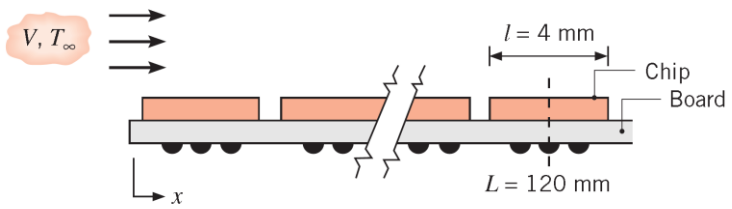
IX. (10pts) Please write down the simplified boundary layer equations for gas flow over a heated flat surface and state the assumptions. Draw schematically the velocity profile and temperature profile across the boundary layer.

X. (10pts) A long copper bar of rectangular cross section, whose width w is much greater than its thickness L, is maintained in contact with a heat sink at its lower surface, and the temperature throughout the bar is approximately equal to that of the sink, T_o. Suddenly, an electric current is passed through the bar and an airstream of temperature T_∞ is passed over the top surface, while the bottom surface continues to be maintained at T_o. Please obtain the governing differential equation and the boundary and initial conditions that could be solved to determine the temperature as a function of position and time in the bar.

XI. (10pts) A stainless steel tube (thermal conductivity k_{st} = 14.4 W/m·K) used to transport a chilled pharmaceutical has an inner diameter of 36 mm and a wall thickness of 2 mm. The pharmaceutical and ambient air are at temperatures of 6 °C and 23 °C, respectively, while the corresponding inner and outer convection coefficients are 400 W/m²·K and 6 W/m²·K, respectively. (a) Sketch the thermal equivalent circuit. (b) What is the heat gain per unit tube length? (c) What is the heat gain per unit length if a 10-mm-thick layer of calcium silicate insulation (k_{ins}=0.05 W/m·K) is applied to the tube?

XII. (10pts) Forced air at T_∞= 25 °C and V = 10 m/s is used to cool electronic elements on a circuit board. One such element is a chip, 4 mm by 4 mm, located 120 mm from the leading edge of the board. Experiments have revealed that flow over the board is disturbed by the elements and that convection heat transfer is correlated by an expression of the form:

$$Nu_x = 0.04 Re_x^{0.85} Pr^{1/3}$$



Estimate the surface temperature of the chip if it is dissipating 40 mW.

Note: 1) Thermophysical properties of air at 25 °C and atmospheric pressure can be approximated as thermal conductivity k = 0.026 W/m·K, kinematic viscosity ν = 1.57x10^{-5} m²/s and Pr = 0.71; 2) For simplified calculation, the average heat transfer coefficient for the chip surface is assumed to be 1.2 times of the local value at x=L.

XIV. (10pts) Liquid oxygen, which has a boiling point of 90 K and a latent heat of vaporization of 214 kJ/kg, stored in a spherical container whose outer surface is of 500-mm diameter and at a temperature of -10°C. The container is housed in a laboratory whose air and walls are at 25°C. If the surface emissivity is 0.20 and the heat transfer coefficient associated with free convection at the outer surface of the container is 10 W/m²·K, what is the rate, in kg/s, at which oxygen vapor must be vented from the system?

XIII. (10pts) A concentric tube heat exchanger for cooling lubricating oil is comprised of a thin-walled inner tube of 25-mm diameter carrying water and an outer tube of 45-mm diameter carrying the oil. The exchanger operates in counterflow with an overall heat transfer coefficient of 60 W/m²·K and the tabulated average properties. (a) If the outlet temperature of the oil is 60°C, determine the total heat transfer and the outlet temperature of the water. (b) Determine the length required for the heat exchanger.

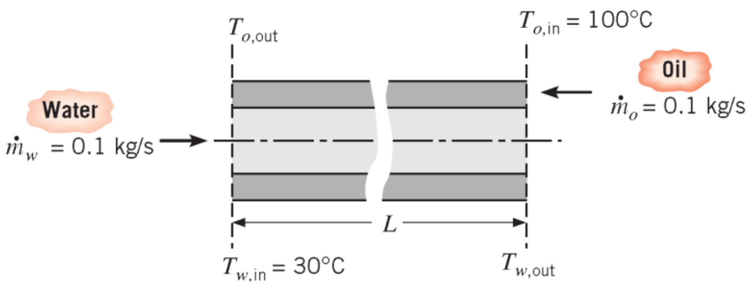
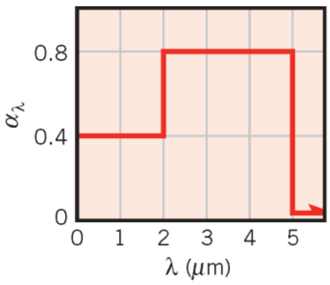


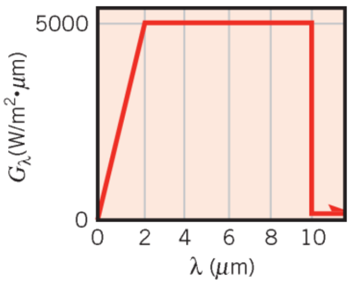
Table:

Properties	Water	Oil
ρ (kg/m^3)	1000	800
c_p (J/kg·K)	4200	1900
ν (m^2/s)	7×10^{-7}	1×10^{-5}
k (W/m·K)	0.64	0.134
Pr	4.7	140

XV. (10pts) Consider an air heater consisting of a semicircular tube for which the plane surface is maintained at 1000 K and the other surface is well insulated. The tube radius is 20 mm, and both surfaces have an emissivity of 0.8. If atmospheric air flows through the tube at 0.01 kg/s and T_m = 400 K, what is the rate at which heat must be supplied per unit length to maintain the plane surface at 1000 K? What is the temperature of the insulated surface?

XVI. (10pts) Consider an opaque, diffuse surface for which the spectral absorptivity and irradiation are as follows:





What is the total absorptivity of the surface for the prescribed irradiation? If the surface is at a temperature of 1250 K, what is its emissive power? How will the surface temperature vary with time for the prescribed conditions, and why?

Supplementary Table: Blackbody Radiation Functions

λT (μm·K)	$F_{(0\to\lambda)}$
2400	0.140
2600	0.183
6200	0.754
6400	0.769