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UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL AND BIO-ENGINEERING TECHNOLOGY

FINAL EXAMINATION

OCTOBER 2025 SEMESTER

COURSE CODE	:	CPD22003
COURSE TITLE	:	HEAT TRANSFER
PROGRAMME NAME	:	DIPLOMA IN CHEMICAL ENGINEERING TECHNOLOGY
DATE	:	24 JANUARY 2026
TIME	:	9:00AM - 12:00PM
DURATION	:	3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper consist of TWO sections.
4. Section A consist 25 MCQ or EMQ questions. Answer ALL questions.
5. Section B consist of four questions. Answer THREE (3) questions only.
6. Please write your answer on the answer booklet provided.
7. Please answer all questions in English only.
8. Please answer MCQ/EMQ questions using OMR sheet. ☐ *Tick if applicable*
9. Refer to the attached Formula/ Appendies. ☐ *Tick if applicable*

THERE ARE 13 PAGES OF QUESTIONS INCLUDING THIS PAGE

SECTION A (Total: 25 marks)

Answer ALL questions.

Please use the objective answer sheet provided.

1. Find the physical property that causes heat to transfer from one body to another.

   A. Velocity

   B. Density

   C. Pressure

   D. Temperature

2. Identify the option that is not a mode of heat transfer.

   A. Conduction

   B. Radiation

   C. Diffusion

   D. Convection

3. State the direction in which heat naturally flows between two bodies.

   A. Solid to fluid

   B. Low energy to high energy

   C. Cold to hot

   D. High temperature to low temperature

4. Identify the material property that primarily determines the rate of heat transfer by conduction.

   A. Density

   B. Viscosity

   C. Thermal conductivity

   D. Pressure

5. Find the SI unit of thermal conductivity.

   A. W/m^2K

   B. J/kgK

   C. W/mK

   D. m^2/s

6. Identify the law that describes heat transfer by conduction.

   A. Boyle's law

   B. Stefan–Boltzmann law

   C. Newton's law

   D. Fourier's law

7. Find the factors on which thermal resistance in conduction depends.

   A. Thickness

   B. Thermal conductivity

   C. Area

   D. All of the above

8. Find the two entities between which heat transfer occurs during convection.

   A. Surface and fluid

   B. Two vacuums

   C. Two solids

   D. Solid and vacuum

9. Find the cause of fluid motion in forced convection.

   A. Buoyancy

   B. Radiation

   C. Fan or pump

   D. Gravity only

10. Find the cause of fluid motion in natural convection.

   A. External force

   B. Pump

   C. Density difference

   D. Pressure

11. State the Nusselt number represents in heat transfer.

   A. Ratio velocity to temperature

   B. Ratio radiation to convection

   C. Ratio conduction to convection

   D. Ratio convective to conductive heat transfer

12. Reynolds number indicates ___________

   A. Radiation

   B. Flow regime

   C. Temperature difference

   D. Heat transfer rate

13. Boundary layer forms in __________

    A. Radiation only

    B. Conduction only

    C. Convection only

    D. All modes

14. Find an example of forced convection.

    A. Boiling water

    B. Hot air rising

    C. Fan cooling a motor

    D. Smoke rising

15. Prandtl number relates __________

    A. Density and viscosity

    B. Momentum and heat diffusion

    C. Heat and mass transfer

    D. Velocity and pressure

16. Find the velocity fluid adjacent to a surface.

    A. Negative

    B. Infinite

    C. Maximum

    D. Zero

17. Radiation heat transfer occurs due to ____________

    A. Molecular collision

    B. Conduction

    C. Fluid motion

    D. Electromagnetic waves

18. Find the range value of emissivity.

    A. −1 to 1

    B. 0 to 1

    C. 0 to 100

    D. 1 to 10

19. Find value of emissivity for a black body.

    A. >1

    B. 0.5

    C. 0

    D. 1

20. Find heat exchanger uses fins.

    A. Plate

    B. Double pipe

    C. Air-cooled

    D. Shell and tube

21. Counter-current heat exchanger is more _____ than parallel flow.

    A. Expensive

    B. Efficient

    C. Compact

    D. Slow

22. Find the meaning of LMTD.

    A. Large mean thermal difference

    B. Log mean temperature difference

    C. Linear mean temperature difference

    D. Long mean temperature difference

23. Find the function of insulator.

    A. Increase temperature

    B. Reduce heat transfer

    C. Increase radiation

    D. Increase heat loss

24. Fouling factor accounts for _________

    A. Surface roughness

    B. Clean surface

    C. Dirt and deposits

    D. Radiation

25. Find the factor that reduced heat loss from pipes.

    A. Polishing

    B. Increasing thickness

    C. Insulation

    D. Increasing velocity

SECTION B (Total: 75 marks)

Answer THREE (3) questions only.

Please use the answer booklet provided.

Question 1

Answer all questions

(a) Define the function of insulator and give 2 examples.

(4 marks)

(b) A steam pipe of inner radius 30 mm is insulated with material of thermal conductivity 0.06 W/m·K. The insulation thickness is 40 mm with inner surface temperature is 180°C and outer surface temperature is 40°C. Calculate the heat loss per meter length of the pipe.

(6 marks)

(c) A furnace wall consists of two layers which are fire bricks with thickness (m) = 0.12 and Thermal Conductivity (W/m·K) = 1.4 and Insulation brick with thickness (m) = 0.08 and Thermal Conductivity (W/m·K) = 0.25. Inner surface temperature is 800°C, outer surface temperature is 50°C. Determine the heat transfer rate per unit area.

(7 marks)

(d) A glass window of width W = 1 m, height H = 2 m and 5 mm thick has a thermal conductivity of k_g =1.4 W/m.K. The inner and outer surface temperatures of the glass are 15°C and -20°C, respectively, on a cold winter day. To reduce heat loss through windows, it is customary to use a double pane construction in which adjoining panes are separated by an air space. If the spacing is 10 mm and the glass surfaces in contact with the air have temperatures of 10°C and -15°C. The thermal conductivity of air is k_a = 0.024 W/m. K.

i. Calculate the rate of heat loss through the glass.

(3 marks)

ii. Calculate the rate of heat loss through the double pane glass.

(5 marks)

Question 2

Answer all questions

(a) Explain the concept of the thermal boundary layer and its importance in convection heat transfer.

(5 marks)

(b) A reactor wall of area 3 m^2 is cooled by water at 30°C. The convection coefficient is 500 $W/m^2 \cdot K$. If the heat loss is 180 kW, calculate the surface temperature of the wall.

(4 marks)

(c) A small hot water tank with a diameter of 5 cm is placed in a large cold room. The room temperature is 10°C, and the outer surface of the tank has a temperature of 35°C. Calculate the rate of heat loss from the water tank.

Properties:

$k = 0.02495$ W/m.K

$\nu = 1.4965 \times 10^{-5}$ m^2/s

Pr = 0.7315

(16 marks)

Question 3

Answer all questions

(a) Define view factor and give the value for plane, convex and concave surfaces.

(5 marks)

(b) A space satellite in the shape of a sphere with a diameter of 1050 cm is traveling in outer space, where its surface temperature is held at T. The sphere sees only outer space, which can be considered as a black body with a temperature of 0 K. The polished surface of the sphere has an emissivity of 0.1. Determine the surface temperature, T (in °C). Given the heat loss by radiation is 19.5 kW.

(8 marks)

(c) A thin aluminum sheet with an emissivity of 0.15 on both sides is placed between two very large parallel plates, which are maintained at uniform temperatures T_1 = 900 K and T_2 = 650 K and have emissivities ε_1 = 0.5 and ε_2 = 0.8, respectively. Determine:

i. The net rate of radiation heat transfer between the two plates per unit surface area of the plates.

(10 marks)

ii. Compare the result with and without the shield in ratio form.

(2 marks)

Question 4

Answer all questions

(a) The most common type of heat exchanger in industrial applications is the shell and tube heat exchanger.

i. Draw a 4-shell-passes and 20-tube-passes shell-and-tube heat exchanger.

(2 marks)

ii. State TWO (2) advantages and TWO (2) disadvantages of using 12 tube passes instead of 2 tube of the same diameter of shell-and-tube heat exchanger.

(4 marks)

(b) In a chemical processing plant, water is used as a cooling medium in a heat exchanger. The cooling water enters the heat exchanger at a temperature of 25°C and flows at a mass flow rate of 0.8 kg/s. During operation, the water absorbs 50 kW of heat from a hot process stream. Given that the specific heat capacity of water is 4.18 kJ/kg·K, determine the outlet temperature of the cooling water.

(4 marks)

(c) In a chemical processing plant, a heat exchanger is used to transfer heat between two process streams. During steady operation, the exchanger transfers heat at a rate of 120 kW. The effective heat transfer surface area of the exchanger is 6 m^2, and the log mean temperature difference (LMTD) between the hot and cold fluids is 40°C. Determine the overall heat transfer coefficient of the heat exchange.

(4 marks)

(d) A 1-2 shell and tube heat exchanger is installed in a process as shown below. The overall heat transfer coefficient for this unit is U = 270 W/m^2.K and Q = 36,000 W of heat are transferred to the cooler steam at steady state. To obtain the desired operating temperature, determine the heat transfer area need to be.

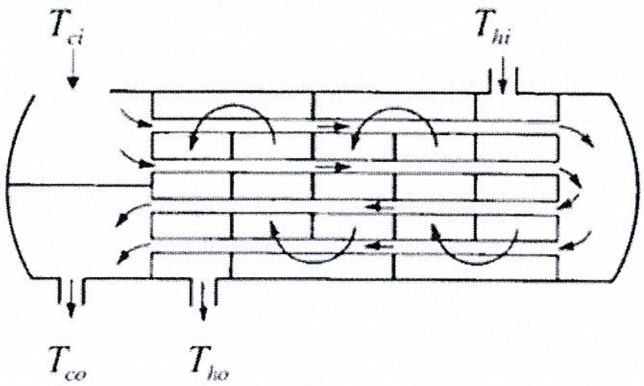
Given Data:

T_{ci} = 25°C

T_{co} = 105°C

T_{hi} = 201°C

T_{ho} = 153°C



Shell and tube heat exchanger

(11 marks)

END OF EXAMINATION PAPER

APPENDICES

$$q = kA\frac{[T_1 - T_2]}{x_2 - x_1}$$

$$T_f = \frac{T_w + T_b}{2}$$

1 W = 1 J/s

$$q_r = 4\pi k\frac{[T_1 - T_2]}{\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}$$

$$R = \frac{\Delta X}{KA}$$

$$q = \frac{\Delta T}{R_{total}}$$

$$q_r = 2\pi kL\frac{[T_1 - T_2]}{\ln\left(\frac{r_2}{r_1}\right)}$$

$$R_{cylinder} = \frac{\ln\left(\frac{r_{out}}{r_{in}}\right)}{2\pi kL}$$

$$q = hA(T_W - T_\infty)$$

$$L_C = \frac{A}{P}$$

$$q = A\sigma T^4$$

$\sigma = 5.67 \times 10^{-8}\ W/m^2.K^4$

$$q = \varepsilon A\sigma(T_1^4 - T_2^4)$$

$\varepsilon = Q/Q_{max}$

$$E_b(T) = \sigma T^4$$

$$q_{12}, plates(no.shield) = \frac{A\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

$$q_{12} one.shield = \frac{A\sigma(T_1^4 - T_2^4)}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right)}$$

$$q_{12\,N-shields} = \frac{A\sigma(T_1^4 - T_2^4)}{(N+1)\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right)} = \frac{1}{N+1}Q_{12,\,no-shields}$$

Cylinders

$$\dot{Q}_{12} = \frac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1-\varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)}$$

Sphere

$$\dot{Q}_{12} = \frac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1-\varepsilon_2}{\varepsilon_2}\left(\frac{r_1}{r_2}\right)^2}$$

$$q = UA(\Delta T)_{lm}$$

$$q = UAF(\Delta T)_{lm}$$

$$R_{total} = \frac{1}{U}$$

$$C_c = \dot{m}_c C_{pc}$$

$$C_h = \dot{m}_h C_{ph}$$

$$c = \frac{C_{min}}{C_{max}}$$

$$NTU = \frac{UAs}{C\min} = \frac{UAs}{(\dot{m}C_p)_{min}}$$

$$q = (m)_{cold}(C_p)_{cold}(\Delta T)_{cold} \qquad q = (m)_{hot}(C_p)_{hot}(\Delta T)_{hot}$$

Parallel $\theta_2 = T_{ho} - T_{co} \qquad \theta_1 = T_{hi} - T_{ci}$

Counter-flow $\theta_1 = T_{hi} - T_{co} \qquad \theta_2 = T_{ho} - T_{ci}$

$$\Delta T_{lm} = \frac{\theta_1 - \theta_2}{\ln\left(\theta_1 / \theta_2\right)}$$

$$Q = m_c C_{pc}(T_{c,out} - T_{c,in}) = m_h C_{ph}(T_{h,in} - T_{h,out})$$

$$\Delta T_{\max} = T_{h,in} - T_{c,in}$$

$$Q_{\max} = (mCp)_{\min}\left(T_{h,inlet} - T_{c,inlet}\right)$$

$$Q = \varepsilon Q_{\max} = \varepsilon(mCp)_{\min}\left(T_{h,inlet} - T_{c,inlet}\right)$$

$$\boldsymbol{Pr = \frac{\nu}{\alpha} = \frac{\mu Cp}{k}}$$

1 W = 1 J/s

$$T_f = \frac{T_w + T_b}{2} \qquad q = \frac{\Delta T}{R_{total}}$$

$$Ra = Gr\,\mathrm{Pr} = \frac{g\beta(Ts - T\infty)Lc^3}{\nu^2}\mathrm{Pr} \qquad \mathrm{Re} = \frac{VLc}{\nu} = \frac{\rho VLc}{\mu}$$

$$Nu = \frac{hLc}{k} \qquad q = hA(T_W - T_\infty) \qquad \nu = \frac{\mu}{\rho}$$

Natural Convection

$$Gr = \frac{g\beta(Ts - T\infty)Lc^3}{\upsilon^2}$$

$\beta = 1/T_f$

$$Ra = Gr\,Pr = \frac{g\beta(Ts - T\infty)Lc^3}{\nu^2}Pr$$

$$Nu = \frac{hL_c}{k} = \left\{0.825 + \frac{0.387\,Ra_L{}^{1/6}}{[1 + (0.492/Pr)^{9/16}]^{\,8/27}}\right\}^2$$ Vertical Plate and Vertical Cylinder

$$Nu = \frac{hL_c}{k} = \left\{0.6 + \frac{0.387\,Ra_D{}^{1/6}}{[1 + (0.559/Pr)^{9/16}]^{\,8/27}}\right\}^2$$ Horizontal Cylinder

$$Nu = \frac{hL_c}{k} = 2 + \frac{0.589\,Ra_D{}^{1/4}}{[1 + (0.469/Pr)^{9/16}]^{4/9}}$$ Sphere

<u>Force Convection</u>

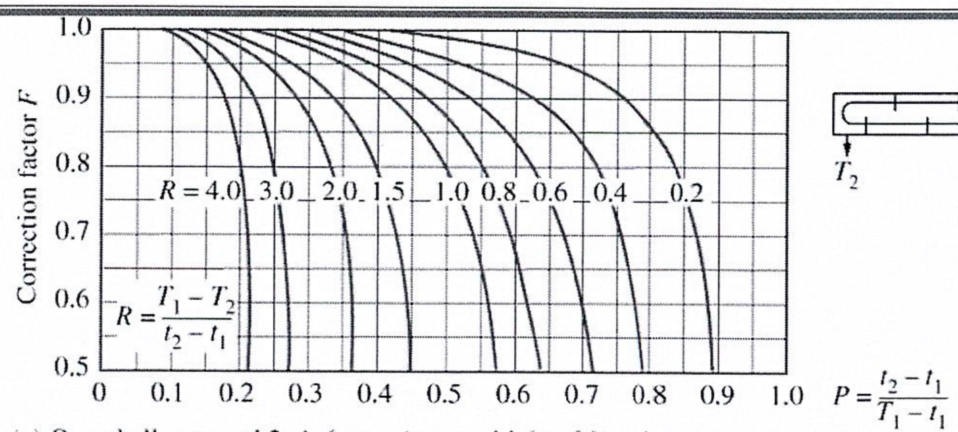
Plates

Re < 5 x 10 ⁵ $$Nu = \frac{hL}{k} = 0.664\,\mathrm{Re}^{0.5}\,\mathrm{Pr}^{1/3}$$ Laminar

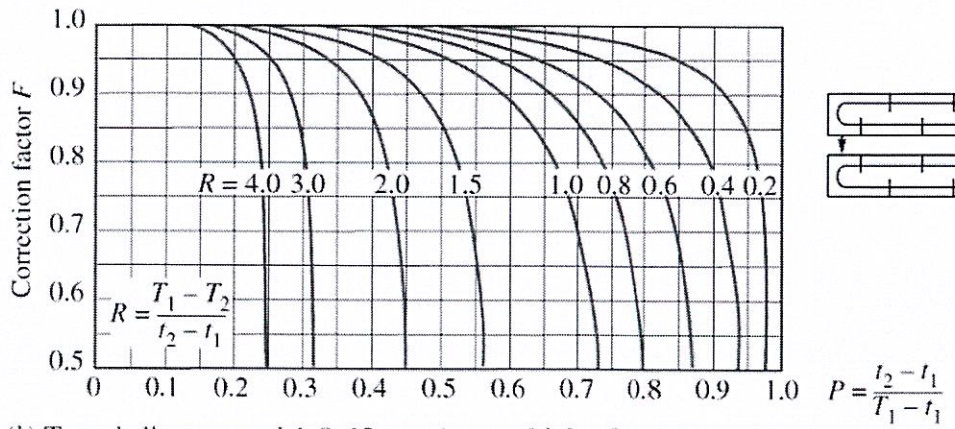
Re > 5 x 10 ⁵ $$Nu = \frac{hL}{k} = 0.0366\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{1/3}$$ Turbulent

$$Nu = \frac{hD}{k} = 0.3 + \frac{0.62\,\mathrm{Re}^{1/2}\,\mathrm{Pr}^{1/3}}{\left[1+(0.4/\mathrm{Pr})^{2/3}\right]^{1/4}}\left[1+(\mathrm{Re}/282000)^{5/8}\right]^{4/5}$$ Cylinder

$$Nu = \frac{hD}{k} = 2.0 + \left[0.4\,Re^{1/2} + 0.06\,Re^{2/3}\right]Pr^{0.4}\left(\frac{\mu_\infty}{\mu_s}\right)^{1/4}$$ Sphere



(*a*) One-shell pass and 2, 4, 6, etc. (any multiple of 2), tube passes



(*b*) Two-shell passes and 4, 8, 12, etc. (any multiple of 4), tube passes