
UNIVERSITI SAINS MALAYSIA

First Semester Examination
2014/2015 Academic Session

December 2014 / January 2015

EMH 441 – Heat Transfer
[Pemindahan Haba]

Duration : 3 hours
Masa : 3 jam

Please check that this paper contains **EIGHT** printed pages and **FIVE** questions before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **LAPAN** mukasurat dan **LIMA** soalan yang bercetak sebelum anda memulakan peperiksaan.]*

INSTRUCTIONS : Answer **ALL** questions.

*[**ARAHAN** : Jawab **SEMUA** soalan.]*

Answer questions in English OR Bahasa Malaysia.

[Jawab soalan dalam Bahasa Inggeris ATAU Bahasa Malaysia.]

Answer to each question must begin from a new page.

[Jawapan bagi setiap soalan mestilah dimulakan pada mukasurat yang baru.]

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

Formula Book is provided.

Buku Formula adalah dibekalkan

- Q1. [a] One way of measuring the thermal conductivity of a material is to sandwich an electric thermo foil heater between two identical rectangular samples of the material and to heavily insulate the four outer edges, as shown in the Figure Q1[a]. Thermocouples attached to the inner and outer surfaces of the samples record the temperatures. During an experiment, two 0.5-cm-thick samples 10 cm X 10 cm in size are used. When steady operation is reached, the heater is observed to draw 35 W of electric power, and the temperature of each sample is observed to drop from 82°C at the inner surface to 74°C at the outer surface. Calculate the thermal conductivity of the material at the average temperature.

Salah satu cara untuk mengukur kekonduksian terma ialah dengan meletakkan pemanas termofoil elektrik di antara dua sampel bahan yang serupa dan menebat empat tepi luar dengan tebal, seperti yang ditunjukkan dalam Rajah S1[a]. Termogandingan melekat pada permukaan dalaman dan luaran sampel untuk merekodkan suhu. Semasa eksperimen, dua sampel 0.5 cm tebal 10 cm X 10 cm digunakan. Apabila operasi mencapai stabil, pemanas menggunakan kuasa elektrik 35 W, dan suhu setiap sampel menurun dari 82° C pada permukaan dalaman hingga 74° C pada permukaan luar. Kirakan kekonduksian bahan tersebut pada suhu purata.

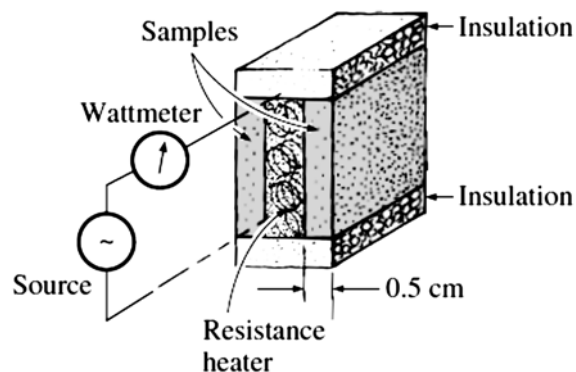


Figure Q1[a]
Rajah S1[a]

(40 marks/markah)

- [b] A 3 mm diameter and 5 m long electric wire is tightly wrapped with a 2 mm thick plastic cover whose thermal conductivity is $k = 0.15 \text{ W/m}\cdot\text{°C}$, as shown in Figure Q1[b]. Electrical measurements indicate that a current of 10A passes through the wire and there is a voltage drop of 8V along the wire. If the insulated wire is exposed to a medium at $T_\infty = 30^\circ\text{C}$ with a heat transfer coefficient of $h = 12 \text{ W/m}^2\cdot\text{°C}$, calculate the temperature at the interface of the wire and the plastic cover in steady operation. Also discuss whether doubling the thickness of the plastic cover will increase or decrease this interface temperature.

Satu wayar elektrik 3 mm diameter dan 5 m panjang dibalut dengan plastik 2 mm tebal yang kekonduksian terma $k = 0.15 \text{ W/m} \cdot ^\circ\text{C}$, seperti yang ditunjukkan dalam Rajah S1[b]. Ukuran elektrik menunjukkan bahawa arus 10A melalui wayar dan terdapat penurunan voltan 8V. Jika wayar bertebat terdedah kepada medium ialah $T_\infty = 30^\circ\text{C}$ dengan pekali pemindahan haba $h = 12 \text{ W/m}^2\text{C}$, tentukan suhu di antara muka wayar dan plastik dalam operasi yang stabil. Juga bincangkan sama ada dua kali ganda ketebalan plastik akan meningkatkan atau mengurangkan suhu antara muka ini.

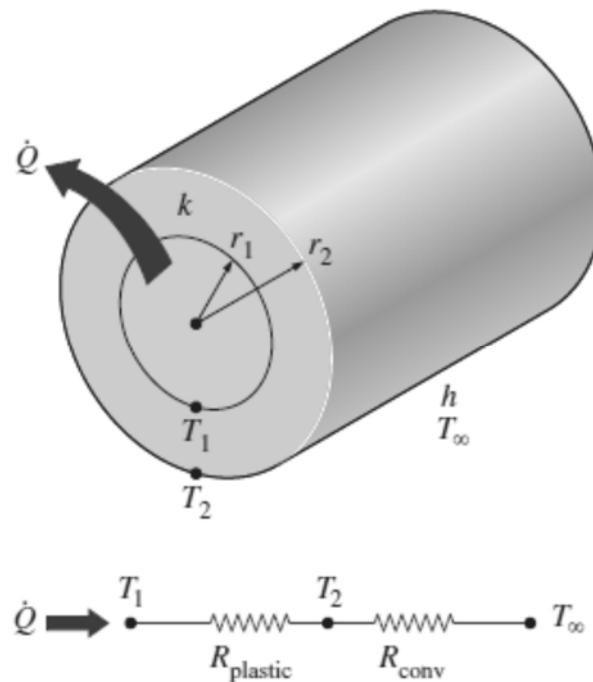


Figure Q1[b]
Rajah S1[b]

(60 marks/markah)

- Q2. [a] An engineer intend to warm up some chemical solution for experiment, he pours the solution into a thin walled glass whose diameter is 6 cm. The height of the solution in the glass is 7 cm. She then places the glass into a large pot filled with hot water at 70°C (as in Figure Q2[a]). The solution is stirred constantly. If the heat transfer coefficient between the water and the glass is $120 \text{ W/m}^2\text{K}$, determine how long it will take for the solution to warm up from 3°C to 38°C . Determine whether estimation of lumped system is acceptable or not. Justify your answer. The thermal conductivity, density, and specific heat of the solution at 20°C are $k = 0.598 \text{ W/m}^\circ\text{C}$, $\rho = 998 \text{ kg/m}^3$, and $c_p = 4.182 \text{ kJ/kg} \cdot ^\circ\text{C}$.

Seorang jurutera memanaskan larutan kimia untuk eksperimen, dia menuangkan larutan ke dalam satu gelas berdinding nipis berdiameter 6 cm. Ketinggian larutan di gelas ialah 7 cm. kemudian dia meletakkan gelas ke dalam periuk besar berisi air panas di 70°C (seperti dalam Rajah S2[a]). Larutan dikacau berterusan. Jika pekali pemindahan haba antara air dan gelas ialah $120 \text{ W/m}^2\cdot\text{K}$, tentukan berapa lama untuk larutan dipanaskan dari 3°C hingga 38°C . Tentukan adakah pengiraan sistem terbungkal boleh diterima. Justifikasikan jawapan anda. Kekonduksian, ketumpatan dan haba tentu larutan pada 20°C adalah $k = 0.598 \text{ W/m}^\circ\text{C}$, $\rho = 998 \text{ kg/m}^3$, dan $c_p = 4,182 \text{ kJ/kg}^\circ\text{C}$.

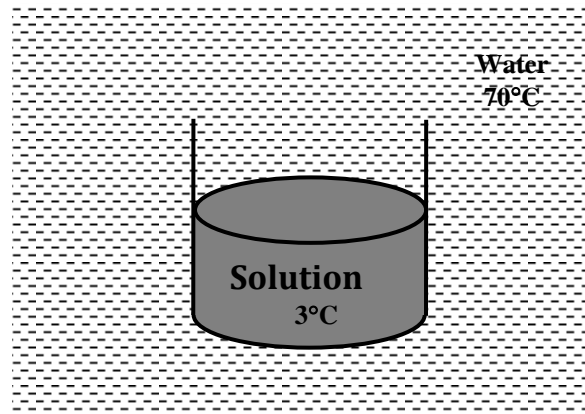


Figure Q2[a]
Rajah S2[a]

(40 marks/markah)

- [b] Carbon steel balls ($k = 54 \text{ W/m}^\circ\text{C}$, $\rho = 7833 \text{ kg/m}^3$, and $c_p = 0.465 \text{ kJ/kg}^\circ\text{C}$) 8 mm in diameter are annealed by heating them first to 900°C in a furnace and then allowing them to cool slowly to 100°C in ambient air at 35°C . If the average heat transfer coefficient is $75 \text{ W/m}^2\cdot\text{K}$, determine how long the annealing process will take. If 2500 balls are to be annealed per hour, calculate the total rate of heat transfer from the balls to the ambient air.

Bola keluli ($k = 54 \text{ W/m}^\circ\text{C}$, $\rho = 7833 \text{ kg/m}^3$, dan $c_p = 0.465 \text{ kJ/kg}^\circ\text{C}$) 8 mm diameter disepuh-lindap dengan memanaskan dulu hingga 900°C dalam relau dan kemudian membolehkan mereka untuk menyejuk perlahan-lahan hingga 100°C dalam udara 35°C . Jika pekali pemindahan haba purata ialah $75 \text{ W/m}^2\cdot\text{K}$, tentukan berapa lama proses penyepuh lindapan yang diperlukan. Jika 2500 bola disepuh-lindap sejam, kirakan jumlah kadar pemindahan haba dari bola ke udara persekitaran .

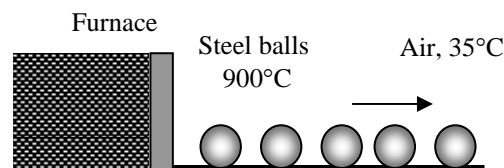


Figure Q2[b]
Rajah S2[b]

(60 marks/markah)

- Q3. [a] The boiling temperature of nitrogen at atmospheric pressure at sea level (1 atm) is -196°C . Therefore, nitrogen is commonly used in low temperature scientific studies since the temperature of liquid nitrogen in a tank open to the atmosphere will remain constant at -196°C until the liquid nitrogen in the tank is depleted. Any heat transfer to the tank will result in the evaporation of some liquid nitrogen, which has a heat of vaporization of 198 kJ/kg and a density of 810 kg/m^3 at 1 atm. Consider a 4-m-diameter spherical tank initially filled with liquid nitrogen at 1 atm and -196°C (as shown in Figure Q3[a]). The tank is exposed to 20°C ambient air with a heat transfer coefficient of $25\text{ W/m}^2\text{C}$. The temperature of the thin-shelled spherical tank is observed to be almost the same as the temperature of the nitrogen inside. Disregarding any radiation heat exchange, calculate the rate of evaporation of the liquid nitrogen in the tank as a result of the heat transfer from the ambient air.

Suhu didih nitrogen pada tekanan atmosfera pada aras laut (1 atm) ialah -196°C . Oleh itu , nitrogen biasanya digunakan dalam kajian saintifik suhu rendah kerana suhu nitrogen cecair di dalam tangki yang terbuka kepada atmosfera akan kekal malar pada -196°C sehingga nitrogen cecair di dalam tangki habis. Sebarang pemindahan haba ke dalam tangki akan menyebabkan penyejatan nitrogen cecair, yang mempunyai haba pengewapan 198 kJ/kg dan ketumpatan 810 kg/m^3 pada 1 atm. Tangki sfera 4 m diameter awalnya dipenuhi dengan nitrogen cecair pada 1 atm dan -196°C (seperti yang ditunjukkan dalam Rajah S3[a]). Tangki terdedah kepada 20°C udara persekitaran dengan pekali pemindahan haba sebanyak $25\text{ W/m}^2\text{C}$. Suhu tangki sfera yang nipis adalah hampir sama dengan suhu nitrogen di dalamnya. Abaikan pertukaran haba radiasi, tentukan kadar penyejatan nitrogen cecair di dalam tangki akibat pemindahan haba dari udara ambien.

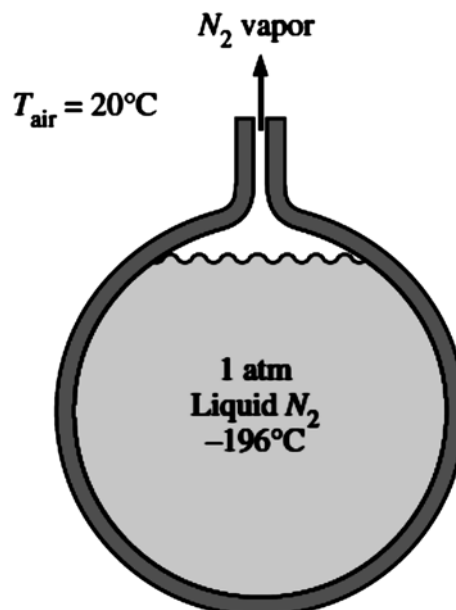


Figure Q3[a]
Rajah S3[a]

(30 marks/markah)

- [b] An incandescent light bulb is an inexpensive but highly inefficient device that converts electrical energy into light. It converts about 10 percent of the electrical energy it consumes into light while converting the remaining 90 percent into heat (as shown in Figure Q3[b]). The glass bulb of the lamp heats up very quickly as a result of absorbing all that heat and dissipating it to the surroundings by convection and radiation. Consider an 8 cm diameter 60W light bulb in a room at 25°C. The emissivity of the glass is 0.9. Assuming that 10 percent of the energy passes through the glass bulb as light with negligible absorption and the rest of the energy is absorbed and dissipated by the bulb itself by natural convection and radiation, determine the surface temperature of the glass bulb. Assume the interior surfaces of the room to be at room temperature. Given $Ra = 2.694 \times 10^6$, $k = 0.03077 \text{ W/m}^\circ\text{C}$, $\nu = 2.279 \times 10^{-5} \text{ m}^2/\text{s}$, and $Pr = 0.7116$.

Satu mentol lampu pijar ialah alat yang murah tetapi sangat tidak cekap untuk menukarkan tenaga elektrik kepada cahaya. Ia menukarkan kira-kira 10 peratus daripada tenaga elektrik kepada cahaya manakala baki 90 peratus menjadi haba (seperti yang ditunjukkan dalam Rajah S3[b]). Kaca lampu panas dengan cepat akibat daripada menyerap semua haba itu dan melepaskan kepersekitaran oleh perolakan dan sinaran. Satu lampu 8 cm diameter 60 W di dalam bilik pada 25°C. Keberpancaran kaca ialah 0.9. Andaikan 10 peratus daripada tenaga melalui kaca sebagai cahaya dan bakinya diserap dan dilesapkan dengan perolakan bebas dan sinaran, tentukan suhu permukaan kaca lampu. Andaikan permukaan bahagian dalam bilik berada pada suhu bilik. Diberi $Ra = 2.694 \times 10^6$, $k = 0.03077 \text{ W/m}^\circ\text{C}$, $\nu = 2.279 \times 10^{-5} \text{ m}^2/\text{s}$, and $Pr = 0.7116$.

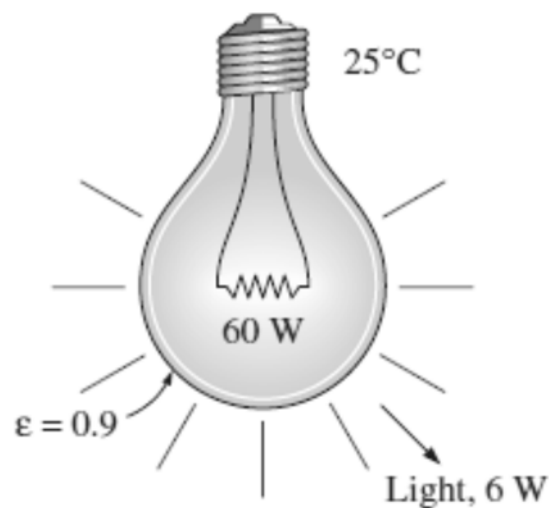


Figure Q3[b]
Rajah S3[b]

(70 marks/markah)

- Q4.** The local atmospheric pressure in Bukit Larut, Taiping (elevation 1610 m), is 83.4 kPa. Air at this pressure and 20°C flows with a velocity of 8 m/s over a 1.5 m x 6 m flat plate whose temperature is 140°C (Figure Q4). Calculate the rate of heat transfer from the plate if the air flows parallel to the (a) 6-m-long side and (b) the 1.5-m side. Given, $k = 0.02953 \text{ W/m}^\circ\text{C}$, $\nu_{@1\text{atm}} = 2.079 \times 10^{-5} \text{ m}^2/\text{s}$, and $Pr = 0.7154$, and $R_{cr} = 5 \times 10^5$.

Tekanan atmosfera di Bukit Larut, Taiping (ketinggian 1610 m), ialah 83.4 kPa. Udara pada tekanan ini dan 20°C mengalir dengan kelajuan 8 m/s ke atas plat 1.5 m X 6 m yang suhu 140 ° C (Rajah S4). Kirakan kadar pemindahan haba dari plat jika udara mengalir selari dengan [a] sebelah 6 m panjang dan [b] sebelah 1.5 m. Diberi, $k = 0.02953 \text{ W/m}^\circ\text{C}$, $\nu_{@1\text{atm}} = 2.079 \times 10^{-5} \text{ m}^2/\text{s}$, and $Pr = 0.7154$, and $R_{cr} = 5 \times 10^5$.

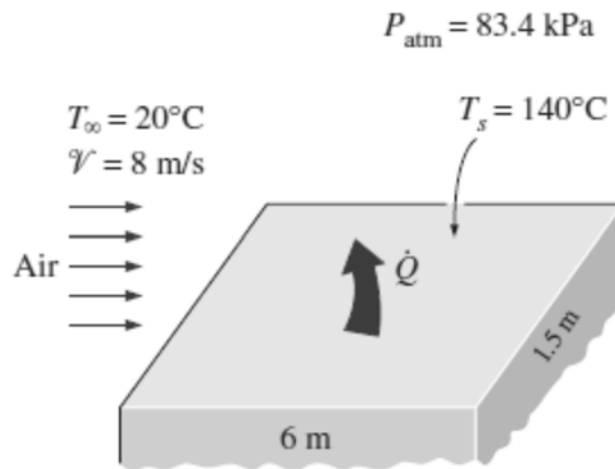


Figure Q4
Rajah S4

(100 marks/markah)

- Q5. [a]** Consider a sealed 20 cm high electronic box whose base dimensions are 40 cm x 40 cm placed in a vacuum chamber (as shown in Figure Q5[a]). The emissivity of the outer surface of the box is 0.95. If the electronic components in the box dissipate a total of 100 W of power and the outer surface temperature of the box is not to exceed 55°C, calculate the temperature at which the surrounding surfaces must be kept if this box is to be cooled by radiation alone. Assume the heat transfer from the bottom surface of the box to the stand to be negligible.

Satu kotak elektrik tertutup 20 cm tinggi berdimensi 40 cm x 40 cm diletakkan di dalam ruang vakum (seperti ditunjukkan Rajah S5[a]). Keberpancaran permukaan luar kotak ialah 0.95. Jika komponen elektronik di dalam kotak melepaskan sejumlah 100 W kuasa dan suhu permukaan luar kotak tidak melebihi 55°C, tentukan suhu sekitar permukaan jika kotak disejukkan oleh radiasi sahaja. Abaikan pemindahan haba dari permukaan bawah kotak ke penyokong.

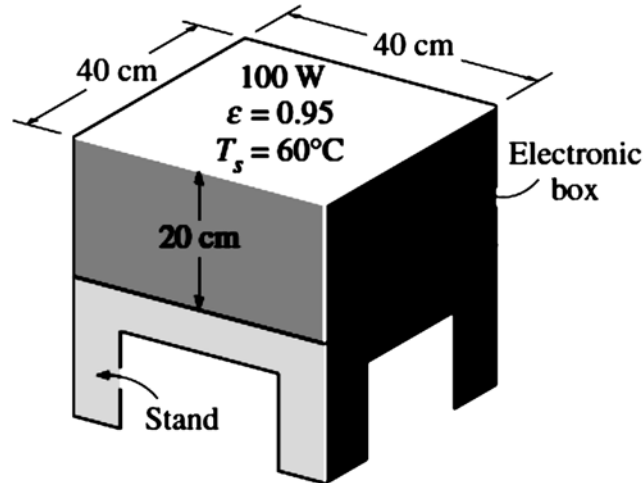


Figure Q5[a]
Rajah S5[a]

(30 marks/markah)

- [b] Consider a 4 m x 4 m x 4 m cubical furnace whose floor and ceiling are black and whose side surfaces are reradiating (as shown in Figure Q5[b]). The floor and the ceiling of the furnace are maintained at temperatures of 550 K and 1100 K, respectively. Calculate the net rate of radiation heat transfer between the floor and the ceiling of the furnace.

Satu kubik relau 4 m x 4 m x 4 m yang lantai dan silingnya ialah hitam dan permukaan tepi adalah beradiasi-semula (seperti yang ditunjukkan dalam Rajah S5[b]). Lantai dan siling relau dikekalkan pada suhu 550 K dan 1100 K, masing-masing. Kirakan kadar bersih pemindahan haba radiasi antara lantai dan siling relau.

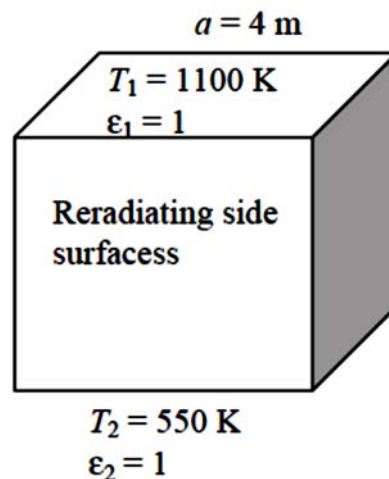


Figure Q5[b]
Rajah S5[b]

(70 marks/markah)