RENCANA PEMBELAJARAN SEMESTER (RPS)
PROGRAM STUDI S1 TEKNIK MESIN
FAKULTAS TEKNIK
UNIVERSITAS SEBELAS MARET

Identitas Mata Kuliah			Identitas dan Validasi		Nama	Tanda Tangan
Kode Mata Kuliah	:	**MS**	Dosen Pengembang RPS	:	Rendy Adhi Rachmanto,S.T.,M.T.	
Nama Mata Kuliah	:	**Perpindahan Panas 2**				
Bobot Mata Kuliah (sks)	:	**3**	Koord. Kelompok Mata Kuliah	:	Prof. Dr. techn. Suyitno,S.T.,M.T.	
Semester	:	**4**				
Mata Kuliah Prasyarat	:	**Perpindahan Panas 1**	Kepala Program Studi	:	Dr. Eng. Syamsul Hadi,S.T.,M.T.	

Capaian Pembelajaran Lulusan (CPL)

Kode CPL		Unsur CPL
CS1 *	:	Menginternalisasi nilai, norma, dan etika akademik
CS2 *	:	Menunjukkan sikap bertanggungjawab atas pekerjaan di bidang keahliannya secara mandiri
CK4 **	:	Mampu menerapkan pemikiran logis, kritis, sistematis dan inovatif dalam kontek pengembangan atau implementasi ilmu pengetahuan dan teknologi yang memperhatikan dan menerapkan nilai humaniora yang seduai dengan bidang keahliannya.
CK6 **	:	Mampu menunjukkan kinerja mandiri, bermutu dan terukur.
CK1 **	:	Mampu menerapkan matematika, sains, danprinsip rekayasa (engineering principles) untuk menyelesaikan masalah rekayasa komples(complex engineering problem)
CK6 **	:	Mampu menunjukkan kinerja mandiri, bermutu dan terukur
CK1 **	:	Menguasai konsep teoretis sains alam, aplikasi matematika rekayasa; prinsip-prinsip rekayasa (engineering fundamentals), sains rekayasa dan perancangan rekayasa yang diperlukan untuk analisis dan perancangan sistem, proses, produk atau komponen

CP Mata kuliah (CPMK) : Mahasiswa mampu menganalisis dan menghitungan permasalahan perpindahan panas konveksi untuk menghasilkan rancangan.

Bahan Kajian Keilmuan : 1. Konversi Energi

Deskripsi Mata Kuliah : Mata kuliah ini berisi perpindahan panas konveksi

Daftar Referensi :

1. Incropera FP, Dewitt DP, Fundamental of Heat Transfer, John Willey and Sons Inc., NY, 1990
2. Welty JR, Wicks CE, Fundamental Momentum, Heat and Mass Transfer, John Willey and Sons Inc., Ny, 2007
3. Holman JP, Heat Transfer, Mc. Graw Hill, Singapore, 1981.

Tahap	Kemampuan akhir	Materi Pokok	Referensi	Metode Pembelajaran	Pengalaman Belajar	Waktu	Penilaian*	
							Indikator/ kode CPL	Teknik penilaian /bobot
1	2	3	4	5	6	7	8	9
1	Mampu menentukan parameter tidak berdimensi dan properti perpindahan panas konveksi	1. Review Perpindahan Panas 1 2. Analisa non dimensi 3. Prototype dan model	1 (bab 6)	Tatap muka, tugas dan quis	Menganalisis dan menghitung.	1 x 150 mnt	S8, S9, KU1, KU2, KK1, KK2, PP1	Tes/20%
2	Mampu menjelaskan aliran fluida	1. Konsep lapis batas	1 (Bab 7)	Tatap muka, tugas dan quis	Menganalisis dan menghitung.	2 x 150 mnt	S8, S9, KU1, KU2,	Tes/15%

	dasar perpindahan panas konveksi	2. Laminar dan turbulen					KK1, KK2, PP1	
3	Mampu menjelaskan aliran luar.	1. Konveksi paksa. 2. Perpindahan panas di aliran pada plat datar, silinder dan bola.	1 (bab 8)	Tatap muka, tugas dan quis	Menganalisis dan menghitung.	2 x 150 mnt	S8, S9, KU1, KU2, KK1, KK2, PP1	Tes/15%
4	Mampu menjelaskan aliran dalam.	1. Perpindahan panas di aliran channel. 2. Perpindahan panas di aliran bundle channel.	1 (Bab 8)	Tatap muka, tugas dan quis	Menganalisis dan menghitung.	3 x 150 mnt	S8, S9, KU1, KU2, KK1, KK2, PP1	Tes/15%
5	Mampu menjelaskan konveksi bebas.	1. Perpindahan panas konveksi bebas laminar dan turbulen	1(bab 9)	Tatap muka, tugas dan quis	Menganalisis dan menghitung.	4 x 150 mnt	S8, S9, KU1, KU2, KK1, KK2, PP1	Tes/10%
6	Mampu menjelaskan kondensasi, evaporasi	1. Perpindahan panas untuk kondensasi dan evaporasi. 2. Kondensasi dan evaporasi di bundle pipa.	1 (Bab 10)	Tatap muka, tugas dan quis	Menganalisi, dan menghitung.	4 x 150 mnt	S8, S9, KU1, KU2, KK1, KK2, PP1	Tes/25%

Mengetahui, Ketua Rumpun Bidang Perancangan dan Rekayasa Prof. Dr.techn. Suyitno,S.T.,M.T.	Surakarta, Agustus 2018 Dosen Pengampu Rendy Adhi Rachmanto,S.T.,M.T.

Menyetujui,
Kepala Program Studi Teknik Mesin
FT UNS

Dr.Eng. Syamsul Hadi, ST., M.T.

KRITERIA PENILAIAN

Kriteria penilain dari kemampuan mahasiswa dapat dilihat dari pekerjaan atau hasil tes. Setiap soal dikerjakan dengan urutan sebagai berikut:

Komponen Pengerjaan Tes	Nilai Maks.
Diberikan: berisi informasi yang diberikan dari soal	5
Ditanya: berisi parameter yang harus dijawab	5
Skematik dan data: berisi gambar/skematik penjelasan dan data	15
Persamaan dasar: dituliskan persamaan-persamaan yang digunakan	10
Assumsi: memberikan assumsi yang digunakan untuk menyelesaikan	10
Analisis: menyederhanakan permsamaan dasar dengan menggunakan assumsi yang menghasilkan persamaan akhir	30
Jawaban: menghitung untuk menghasilkan jawaban	20
Komentar: memberikan komentar terhadap permasalahan/soal	5
Total	100

Bentuk dari tes dapat dipelajari dari contoh soal pada masing-masing bab pada buku Referensi 1.

Penentuan nilai akhir:

No.	Komponen	Bobot
1	UTS	50%
2	UAS	50%
		100%

KISI-KISI UJIAN TENGAH SEMESTER
Perpindahan Panas 2

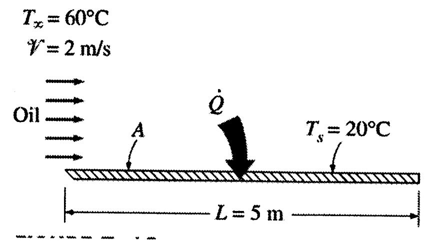
Program Studi : S1 Teknik Mesin
Kompetensi Lulusan : mampu menganalisis dan menghitungan permasalahan perpindahan panas konveksi untuk dasar menghasilkan rancangan.
Mata Kuliah : Perpindahan Panas 2
Bobot : 3 SKS
Semester : IV

KOMPETENSI DASAR	INDIKATOR	SOAL	BOBOT
Mampu menghitung perpindahan konveksi aliran luar	1. Mengidentifikasi masalah 2. Mengaplikasikan persamaan untuk menyelesaikan konveksi aliran luar.	Engine oil at 60°C flows over the upper surface of a 5-m-long flat plate whose temperature is 20°C with a velocity of 2 m/s. Determine the total drag force and the rate of heat transfer per unit width of the entire plate.	50%
Mampu menghitung perpindahan konveksi aliran dalam	1. Mengidentifikasi masalah 2. Mengaplikasikan persamaan untuk menyelesaikan konveksi aliran di bundel.	A 2.2-cm-outer-diameter pipe is to cross a river at a 30-m-wide section while being completely immersed in water. The average flow velocity of water is 4 m/s and the water temperature is 15 C. Determine the drag force ex- erted on the pipe by the river.	50%

UJIAN TENGAH SEMESTER (UTS)
Perpindahan Panas 2
Open text book
WAKTU : 120 MENIT

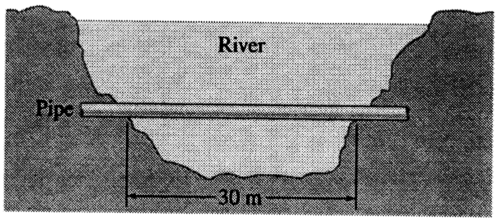
I. 50%

Engine oil at 60°C flows over the upper surface of a 5-m-long flat plate whose temperature is 20°C with a velocity of 2 m/s. Determine the total drag force and the rate of heat transfer per unit width of the entire plate.



II. 50%

A 2.2-cm-outer-diameter pipe is to cross a river at a 30-m-wide section while being completely immersed in water. The average flow velocity of water is 4 m/s and the water temperature is 15 C. Determine the drag force exerted on the pipe by the river.



RUBRIK PENILAIAN INSTRUMEN UTS

Perpindahan Panas 2

Butir I	NILAI
SOLUTION Engine oil flows over a flat plate. The total drag force and the rate of heat transfer per unit width of the plate are to be determined. ***Assumptions*** 1 The flow is steady and incompressible. 2 The critical Reynolds number is $Re_{cr} = 5 \times 10^5$.	5
Properties The properties of engine oil at the film temperature of $T_f = (T_s + T_\infty)/2 = (20 + 60)/2 = 40°C$ are (Table A–14). $\rho = 876\ kg/m^3$ $\quad$ $Pr = 2870$ $k = 0.144\ W/m \cdot °C$ $\quad$ $\nu = 242 \times 10^{-6}\ m^2/s$	10
Analysis Noting that $L = 5$ m, the Reynolds number at the end of the plate is $Re_L = \frac{\mathcal{V}L}{\nu} = \frac{(2\ m/s)(5\ m)}{0.242 \times 10^{-5}\ m^2/s} = 4.13 \times 10^4$ which is less than the critical Reynolds number. Thus we have *laminar flow* over the entire plate, and the average friction coefficient is $C_f = 1.328\ Re_L^{-0.5} = 1.328 \times (4.13 \times 10^3)^{-0.5} = 0.0207$ Noting that the pressure drag is zero and thus $C_D = C_f$ for a flat plate, the drag force acting on the plate per unit width becomes $F_D = C_f A_s \frac{\rho \mathcal{V}^2}{2} = 0.0207 \times (5 \times 1\ m^2) \frac{(876\ kg/m^3)(2\ m/s)^2}{2} \left(\frac{1\ N}{1\ kg \cdot m/s^2}\right) = 181\ N$ The total drag force acting on the entire plate can be determined by multiplying the value obtained above by the width of the plate. This force per unit width corresponds to the weight of a mass of about 18 kg. Therefore, a person who applies an equal and opposite force to the plate to keep it from moving will feel like he or she is using as much force as is necessary to hold a 18-kg mass from dropping. Similarly, the Nusselt number is determined using the laminar flow relations for a flat plate, $Nu = \frac{hL}{k} = 0.664\ Re_L^{0.5}\ Pr^{1/3} = 0.664 \times (4.13 \times 10^4)^{0.5} \times 2870^{1/3} = 1918$ Then, $h = \frac{k}{L} Nu = \frac{0.144\ W/m \cdot °C}{5\ m}(1918) = 55.2\ W/m^2 \cdot °C$	50
and $\dot{Q} = hA_s(T_\infty - T_s) = (55.2\ W/m^2 \cdot °C)(5 \times 1\ m^2)(60 - 20)°C = 11{,}040\ W$	30
Discussion Note that heat transfer is always from the higher-temperature medium to the lower-temperature one. In this case, it is from the oil to the plate. The heat transfer rate is per m width of the plate. The heat transfer for the entire plate can be obtained by multiplying the value obtained by the actual width of the plate.	5
	100

Butir II	NILAI
SOLUTION A pipe is crossing a river. The drag force that acts on the pipe is to be determined. ***Assumptions*** **1** The outer surface of the pipe is smooth so that Figure 7–17 can be used to determine the drag coefficient. **2** Water flow in the river is steady. **3** The direction of water flow is normal to the pipe. **4** Turbulence in river flow is not considered. ***Properties*** The density and dynamic viscosity of water at 15°C are ρ = 999.1 kg/m³ and μ = 1.138 × 10⁻³ kg/m · s (Table A-9).	5
Analysis Noting that D = 0.022 m, the Reynolds number for flow over the pipe is	10
$\mathrm{Re} = \frac{\mathcal{V}D}{\nu} = \frac{\rho \mathcal{V} D}{\mu} = \frac{(999.1\ \mathrm{kg/m^3})(4\ \mathrm{m/s})(0.022\ \mathrm{m})}{1.138 \times 10^{-3}\ \mathrm{kg/m \cdot s}} = 7.73 \times 10^4$	50
The drag coefficient corresponding to this value is, from Figure 7-17, C_D = 1.0. Also, the frontal area for flow past a cylinder is $A = LD$. Then the drag force acting on the pipe becomes $F_D = C_D A \frac{\rho \mathcal{V}^2}{2} = 1.0(30 \times 0.022\ \mathrm{m^2}) \frac{(999.1\ \mathrm{kg/m^3})(4\ \mathrm{m/s})^2}{2} \left(\frac{1\ \mathrm{N}}{1\ \mathrm{kg \cdot m/s^2}}\right)$ $= 5275\ \mathrm{N}$	30
Discussion Note that this force is equivalent to the weight of a mass over 500 kg. Therefore, the drag force the river exerts on the pipe is equivalent to hanging a total of over 500 kg in mass on the pipe supported at its ends 30 m apart. The necessary precautions should be taken if the pipe cannot support this force.	5
	100

Nilai Akhir UTS

No.	SOAL	NILAI	BOBOT	NILAI UTS
1	Butir I	100	50%	50
2	Butir II	100	55%	50
			100%	100

KISI-KISI UJIAN AKHIR SEMESTER
Perpindahan Panas 2

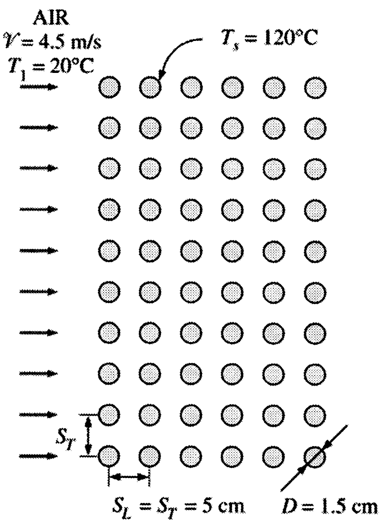
Program Studi	:	S1 Teknik Mesin
Kompetensi Lulusan	:	mampu menganaisis dan menghitungan permasalahan perpindahan panas konveksi untuk dasar menghasilkan rancangan.
Mata Kuliah	:	Perpindahab Panas 2
Bobot	:	3 SKS
Semester	:	IV

KOMPETENSI DASAR	INDIKATOR	SOAL	BOBOT
Mampu menghitung perpindahan panas konveksi di bundel pipa	1. Mengidentifikasi masalah 2. Mengaplikasikan Persamaan perpindahan panas untuk bundel pipa.	In an industrial facility, air is to be preheated before entering a furnace by geo- thermal water at 120C flowing through the tubes of a tube bank located in a duct. Air enters the duct at 20C and 1 atm with a mean velocity of 4.5 m/s, and flows over the tubes in normal direction. The outer diameter of the tubes is 1.5 cm, and the tubes are arranged in-line with longitudinal and transverse pitches of S_L S_T 5 cm. There are 6 rows in the flow direction with 10 tubes in each row. Determine the rate of heat transfer per unit length of the tubes, and the pressure drop across the tube bank.	50%
Mampu menjelaskan dan menghitung evaporasi dan condensasi di internal tube.	1. Mengidentifikasi masalah 2. Menghitung evaporasi atau boiling	Water is boiled at atmospheric pressure by a horizontal polished copper heating element of diameter *D* 5 mm and emissivity 0.05 immersed in water. If the surface temperature of the heating wire is 350°C, determine the rate of heat transfer from the wire to the water per unit length of the wire.	50 %

UJIAN AKHIR SEMESTER (UAS)
Perpindahan Panas 2
Open text book
WAKTU : 120 MENIT

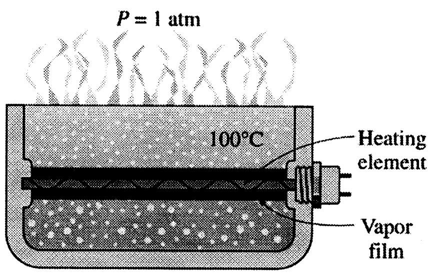
I. 50%

In an industrial facility, air is to be preheated before entering a furnace by geo- thermal water at 120C flowing through the tubes of a tube bank located in a duct. Air enters the duct at 20C and 1 atm with a mean velocity of 4.5 m/s, and flows over the tubes in normal direction. The outer diameter of the tubes is 1.5 cm, and the tubes are arranged in-line with longitudinal and transverse pitches of S_L S_T 5 cm. There are 6 rows in the flow direction with 10 tubes in each row. Determine the rate of heat transfer per unit length of the tubes, and the pressure drop across the tube bank.



II. 50%

Water is boiled at atmospheric pressure by a horizontal polished copper heating element of diameter *D* 5 mm and emissivity 0.05 immersed in water. If the surface temperature of the heating wire is 350°C, determine the rate of heat transfer from the wire to the water per unit length of the wire.



Perpindahan Panas 2

Butir I	NILAI

Assumptions 1 Steady operating conditions exist. 2 The surface temperature of the tubes is equal to the temperature of geothermal water. 5

Properties The exit temperature of air, and thus the mean temperature, is not known. We evaluate the air properties at the assumed mean temperature of 60°C (will be checked later) and 1 atm are Table A–15): 10

$$k = 0.02808 \text{ W/m}\cdot\text{K}, \qquad \rho = 1.06 \text{ kg/m}^3$$
$$C_p = 1.007 \text{ kJ/kg}\cdot\text{K}, \qquad \text{Pr} = 0.7202$$
$$\mu = 2.008\times10^{-5} \text{ kg/m}\cdot\text{s} \qquad \text{Pr}_s = \text{Pr}_{@T_s} = 0.7073$$

Also, the density of air at the inlet temperature of 20°C (for use in the mass flow rate calculation at the inlet) is $\rho_1 = 1.204$ kg/m^3

Analysis It is given that $D = 0.015$ m, $S_L = S_T = 0.05$ m, and $\mathcal{V} = 4.5$ m/s. Then the maximum velocity and the Reynolds number based on the maximum velocity become 50

$$\mathcal{V}_{max} = \frac{S_T}{S_T - D}\mathcal{V} = \frac{0.05}{0.05 - 0.015}(4.5 \text{ m/s}) = 6.43 \text{ m/s}$$
$$\text{Re}_D = \frac{\rho\mathcal{V}_{max}D}{\mu} = \frac{(1.06 \text{ kg/m}^3)(6.43 \text{ m/s})(0.015 \text{ m})}{2.008\times10^{-5} \text{ kg/m}\cdot\text{s}} = 5091$$

The average Nusselt number is determined using the proper relation from Table 7–2 to be

$$\text{Nu}_D = 0.27\,\text{Re}_D^{0.63}\,\text{Pr}^{0.36}(\text{Pr}/\text{Pr}_s)^{0.25}$$
$$= 0.27(5091)^{0.63}(0.7202)^{0.36}(0.7202/0.7073)^{0.25} = 52.2$$

This Nusselt number is applicable to tube banks with $N_L > 16$. In our case, the number of rows is $N_L = 6$, and the corresponding correction factor from Table 7–3 is $F = 0.945$. Then the average Nusselt number and heat transfer coefficient for all the tubes in the tube bank become

$$\text{Nu}_{D,N_L} = F\,\text{Nu}_D = (0.945)(52.2) = 49.3$$
$$h = \frac{\text{Nu}_{D,N_L}k}{D} = \frac{49.3(0.02808 \text{ W/m}\cdot{}^\circ\text{C})}{0.015 \text{ m}} = 92.2 \text{ W/m}^2\cdot{}^\circ\text{C}$$

The total number of tubes is $N = N_L \times N_T = 6 \times 10 = 60$. For a unit tube length ($L = 1$ m), the heat transfer surface area and the mass flow rate of air (evaluated at the inlet) are

$$A_s = N\pi DL = 60\pi(0.015 \text{ m})(1 \text{ m}) = 2.827 \text{ m}^2$$

$$\dot{m} = \dot{m}_1 = \rho_1\mathcal{V}(N_T S_T L)$$
$$= (1.204 \text{ kg/m}^3)(4.5 \text{ m/s})(10)(0.05 \text{ m})(1 \text{ m}) = 2.709 \text{ kg/s}$$

Then the fluid exit temperature, the log mean temperature difference, and the rate of heat transfer become

$$T_e = T_s - (T_s - T_i)\exp\left(-\frac{A_s h}{\dot{m}C_p}\right)$$
$$= 120 - (120 - 20)\exp\left(-\frac{(2.827 \text{ m}^2)(92.2 \text{ W/m}^2\cdot{}^\circ\text{C})}{(2.709 \text{ kg/s})(1007 \text{ J/kg}\cdot{}^\circ\text{C})}\right) = 29.11^\circ\text{C}$$

$$\Delta T_{\ln} = \frac{(T_s - T_e) - (T_s - T_i)}{\ln[(T_s - T_e)/(T_s - T_i)]} = \frac{(120 - 29.11) - (120 - 20)}{\ln[(120 - 29.11)/(120 - 20)]} = 95.4°\text{C}$$

$$\dot{Q} = hA_s\Delta T_{\ln} = (92.2\ \text{W/m}^2 \cdot °\text{C})(2.827\ \text{m}^2)(95.4°\text{C}) = 2.49 \times 10^4\ \text{W}$$

The rate of heat transfer can also be determined in a simpler way from

$$\dot{Q} = hA_s\Delta T_{\ln} = \dot{m}C_p(T_e - T_i)$$
$$= (2.709\ \text{kg/s})(1007\ \text{J/kg} \cdot °\text{C})(29.11 - 20)°\text{C} = 2.49 \times 10^4\ \text{W}$$

For this square in-line tube bank, the friction coefficient corresponding to $\text{Re}_D = 5088$ and $S_L/D = 5/1.5 = 3.33$ is, from Fig. 7–27*a*, $f = 0.16$. Also, $\chi = 1$ for the square arrangements. Then the pressure drop across the tube bank becomes

$$\Delta P = N_L f \chi \frac{\rho V_{\max}^2}{2}$$
$$= 6(0.16)(1)\frac{(1.06\ \text{kg/m}^3)(6.43\ \text{m/s})^3}{2}\left(\frac{1\text{N}}{1\ \text{kg} \cdot \text{m/s}^2}\right) = 21\ \text{Pa}$$

Discussion The arithmetic mean fluid temperature is $(T_i + T_e)/2 = (20 + 110.9)/2 = 65.4°\text{C}$, which is fairly close to the assumed value of 60°C. Therefore, there is no need to repeat calculations by reevaluating the properties at 65.4°C (it can be shown that doing so would change the results by less than 1 percent, which is much less than the uncertainty in the equations and the charts used).

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5

100

Butir II	NILAI

SOLUTION Water is boiled at 1 atm by a horizontal polished copper heating element. The rate of heat transfer to the water per unit length of the heater is to be determined.

Assumptions 1 Steady operating conditions exist. 2 Heat losses from the boiler are negligible. 5

Properties The properties of water at the saturation temperature of 100°C are $h_{fg} = 2257 \times 10^3$ J/kg and $\rho_l = 957.9$ kg/m³ (Table A-9). The properties of vapor at the film temperature of $T_f = (T_{sat} + T_s)/2 = (100 + 350)/2 = 225°C$ = 498 K (which is sufficiently close to 500 K) are, from Table A-16, 10

$$\rho_v = 0.441 \text{ kg/m}^3 \qquad C_{pv} = 1977 \text{ J/kg} \cdot °\text{C}$$
$$\mu_v = 1.73 \times 10^{-5} \text{ kg/m} \cdot \text{s} \qquad k_v = 0.0357 \text{ W/m} \cdot °\text{C}$$

Note that we expressed the properties in units that will cancel each other in boiling heat transfer relations. Also note that we used vapor properties at 1 atm pressure from Table A-16 instead of the properties of saturated vapor from Table A-9 at 250°C since the latter are at the saturation pressure of 4.0 MPa.

Analysis The excess temperature in this case is $\Delta T = T_s - T_{sat} = 350 - 100 = 250°C$, which is much larger than 30°C for water. Therefore, film boiling will occur. The film boiling heat flux in this case can be determined from Eq. 10-5 to be 50

$$\dot{q}_{film} = 0.62\left[\frac{g k_v^3 \rho_v(\rho_l - \rho_v)[h_{fg} + 0.4C_{pv}(T_s - T_{sat})]}{\mu_v D(T_s - T_{sat})}\right]^{1/4}(T_s - T_{sat})$$
$$= 0.62\left[\frac{9.81(0.0357)^3(0.441)(957.9 - 0.441)[(2257 \times 10^3 + 0.4 \times 1977(250)]}{(1.73 \times 10^{-5})(5 \times 10^{-3})(250)}\right]^{1/4} \times 250$$
$$= 5.93 \times 10^4 \text{ W/m}^2$$

The radiation heat flux is determined from Eq. 10-6 to be

$$\dot{q}_{rad} = \varepsilon\sigma(T_s^4 - T_{sat}^4)$$
$$= (0.05)(5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)[(250 + 273 \text{ K})^4 - (100 + 273 \text{ K})^4]$$
$$= 157 \text{ W/m}^2$$

Note that heat transfer by radiation is negligible in this case because of the low emissivity of the surface and the relatively low surface temperature of the heating element. Then the total heat flux becomes (Eq. 10-7)

$$\dot{q}_{total} = \dot{q}_{film} + \frac{3}{4}\dot{q}_{rad} = 5.93 \times 10^4 + \frac{3}{4} \times 157 = 5.94 \times 10^4 \text{ W/m}^2$$

Finally, the rate of heat transfer from the heating element to the water is determined by multiplying the heat flux by the heat transfer surface area,

$$\dot{Q}_{total} = A\dot{q}_{total} = (\pi DL)\dot{q}_{total}$$
$$= (\pi \times 0.005 \text{ m} \times 1 \text{ m})(5.94 \times 10^4 \text{ W/m}^2)$$
$$= 933 \text{ W}$$

30

Discussion Note that the 5-mm-diameter copper heating element will consume about 1 kW of electric power per unit length in steady operation in the film boiling regime. This energy is transferred to the water through the vapor film that forms around the wire. 5

	100

Nilai Akhir UAS

No.	SOAL	NILAI	BOBOT	NILAI UAS
1	Butir I	100	50%	50
2	Butir II	100	50%	50
			100%	100