UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2005/2006

April/Mei 2006

EKC 213 – Pemindahan Haba Proses

Masa : 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi TUJUH muka surat yang bercetak dan SEBELAS muka surat Lampiran sebelum anda memulakan peperiksaan ini.

Arahan: Jawab **LIMA** (5) soalan. Jawab **SEMUA** soalan dari Bahagian A. Jawab mana-mana **DUA** (2) soalan dari Bahagian B.

Pelajar boleh menjawab semua soalan dalam Bahasa Malaysia. Jika pelajar ingin menjawab dalam Bahasa Inggeris, pelajar hendaklah menjawab sekurang-kurangnya SATU soalan dalam Bahasa Malaysia.

Bahagian A : Jawab SEMUA soalan.
Section A : Answer ALL questions.

1. [a] Satu dinding satah, ia pada permulaannya berada pada suhu seragam dengan satu sisi pada 100°C, manakala satu sisi lagi didedahkan kepada satu proses perolakan dengan suatu bendalir pada suhu 10°C, mempunyai pekali pemindahan haba perolakan 10.0 W/m^2K. Dinding tersebut mempunyai keberaliran haba 1.6 W/mK dan berketebalan 40 sm. Kirakan

[i] Kadar pemindahan haba melalui dinding tersebut.

[4 markah]

[ii] Suhu dinding pada sisi sebelahnya.

[4 markah]

[b] Satu tangki sfera untuk penyimpanan oksigen cecair di dalam kapal angkasa dengan diameternya 8 sm telah dipanaskan ke suhu 150°C dan dipasang di dalam ruangan besar yang mana suhu ruang tersebut disenggarakan pada 20°C. Keberpancaran permukaan adalah 0.65 dan Pekali Stefan Boltzman adalah 5.669×10^{-8} W/mK^4. Kirakan

[i] Kehilangan haba radiasi.

[4 markah]

[ii] Suhu ruangan besar jika kehilangan haba adalah 1.76 kW.

[5 markah]

1. [a] A plane wall is initially at a uniform temperature with one side at 100°C, while the other side is exposed to a convection process with a fluid at temperature 10°C, having a convection heat-transfer coefficient of 10.0 W/m^2K. The wall has a thermal conductivity of 1.6 W/mK and is 40 cm thick. Calculate

[i] The heat-transfer rate through the wall.

[4 marks]

[ii] The temperature of the other side of the wall.

[4 marks]

[b] A spherical tank for storing liquid oxygen on the space shuttle with 8 cm diameter is heated to a temperature of 150°C and is installed in a large compartment whose temperature is to be maintained at 20°C. The surface emissivity is 0.65 and Stefan Boltzman constant is 5.669×10^{-8} W/mK^4. Calculate

[i] The radiant heat loss.

[4 marks]

[ii] The large compartment temperature if the radiant heat loss is 1.76 kW.

[5 marks]

...3/-

2. [a] Tangki kontena sfera digunakan untuk suatu ujikaji telah dibina menggunakan aluminium dengan diameter dalaman 0.04 m dan diameter luaran 0.08 m. Suhu dalaman adalah 100°C dan suhu luaran adalah 50°C. Jika keberaliran haba Aluminium adalah 204 W/mK, kirakan:

[i] Pemindahan haba dari dalaman ke luaran kontena tersebut.

[4 markah]

[ii] Rintangan haba kontena aluminium tersebut.

[4 markah]

[b] Anggap bahawa sfera dalam soalan [a] diselaputi dengan 1.0 sm lapisan bahan penebat yang mempunyai keberaliran haba 0.05 W/mK dan luaran penebat didedahkan kepada persekitaran dengan pekali pemindahan haba bersamaan 20 W/m^2K dan pada suhu 10°C. Dalaman sfera tersebut kekal pada suhu 100°C. Kirakan

[i] Rintangan haba bahan penebat.

[4 markah]

[ii] Kadar pemindahan haba di bawah keadaan tersebut.

[5 markah]

2. *[a] A spherical container tank used for an experimental test is constructed of aluminium with an inner diameter of 0.04 m and an outer diameter of 0.08 m. The inside temperature is 100°C and the outer temperature 50°C. If the thermal conductivity of Aluminium is 204 W/mK, calculate:*

[i] The heat transfer from the inside to the outside of the container

[4 marks]

[ii] The thermal resistance of the aluminum container

[4 marks]

[b] Assume that the sphere in above question [a] is covered with a 1.0 cm layer of an insulating material having thermal conductivity 0.05 W/mK and the outside of the insulation is exposed to an environment with heat-transfer coefficient is equal to 20 W/m^2K and temperature is 10°C. The inside of the sphere remains at 100°C. Calculate

[i] The thermal resistance of the insulating material.

[4 marks]

[ii] The heat-transfer rate under these conditions.

[5 marks]

...4/-

3. [a] Bagi menguji prinsip pemindahan haba perolakan, Helium diperlukan bagi ujian tersebut pada tekanan 150 kPa dan suhu 20°C mengalir merentasi plat berkeluasan 1.0 m^2 dan pada halaju 50 m/s. Plat dikekalkan pada suhu 100°C. Kirakan haba yang hilang dari plat tersebut (anggapkan panjang bersamaan dengan satu meter).

[5 markah]

[b] Etilena glikol perlu disejukkan dari 60 ke 40°C dalam tiub berdiameter 3 sm bagi ujian pemindahan haba perolakan. Suhu dinding tiub dikekalkan pada suhu 20°C. Gliko tersebut memasuki tiub dengan halaju 10 m/s. Kirakan panjang tiub yang diperlukan untuk penyejukan paksa ini.

[5 markah]

[c] Satu pemanas minyak-enjin terdiri daripada tangki besar dengan satu pemanas elektrik berpermukaan plat segiempat sama di bahagian bawah tangki tersebut. Plat pemanas bersaiz 30 sm dengan 30 sm dan dikekalkan pada suhu 60°C. Kirakan kadar pemindahan haba disebabkan perolakan semulajadi bagi suhu minyak pada 20°C.

[6 markah]

3. [a] In order to test the principles of convection heat-transfer it is necessary to use Helium for the test at a pressure of 150 kPa and a temperature of 20°C flows across an area of 1.0 m^2 plate at a velocity of 50 m/s. The plate is maintained at a constant temperature of 100°C. Calculate the heat lost by the plate. (assuming that the length is equal to one meter).

[5 marks]

[b] Ethylene glycol is to be cooled, for the test to be made for the convection heat-transfer, from 60 to 40°C in a 3 cm diameter tube. The tube wall temperature is maintained constant at 20°C. The glycol enters the tube with a velocity of 10 m/s. Calculate the length of the tube necessary for this forced cooling.

[5 marks]

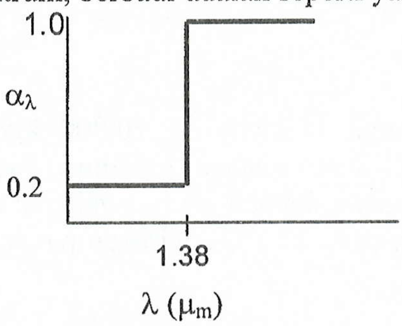
[c] An engine-oil heater consists of large vessel with a square plate electrical heater surface in the bottom of the vessel. The heater plate is 30 by 30 cm and is maintained at a constant temperature of 60°C. Calculate the natural convection heat-transfer rate due to natural convection for an oil temperature of 20°C.

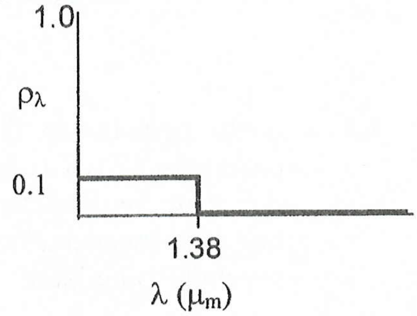
[6 marks]

...5/-

Bahagian B : Jawab mana-mana DUA soalan.
Section B : Answer any TWO questions.

4. Keberserapan spektrum, α_λ dan kepantulan spektrum, ρ_λ bagi bahan pilihan secara spektrum, berbaur adalah seperti yang ditunjukkan di bawah:





[a] Lakarkan spektrum kepindahan, τ_λ.

[5 markah]

[b] Sekiranya penyinaran suria dengan $G_s = 750\ W/m^2$ dan taburan spektrum bagi badan hitam pada 5800 K melanggar bahan tersebut, kirakan pecahan-pecahan sinaran yang dipindah, dipantul dan diserap oleh bahan itu.

[8 markah]

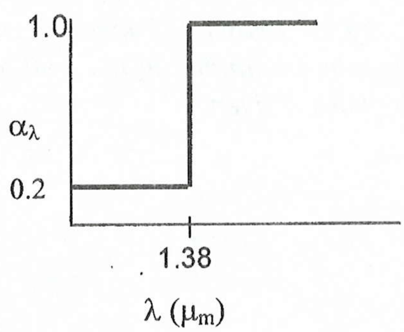
[c] Sekiranya suhu bahan itu ialah 350 K, kirakan keberpancaran, ε_λ.

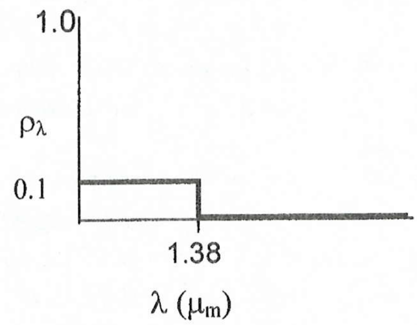
[7 markah]

[d] Tentukan fluks haba bersih penyinaran kepada bahan itu.

[5 markah]

4. The spectral absorptivity, α_λ and spectral reflectivity, ρ_λ for a spectrally selective, diffuse material are shown below:





[a] Sketch the spectral transmissivity, τ_λ.

[5 marks]

[b] If solar irradiation with $G_s = 750\ W/m^2$ and the spectral distribution of a blackbody at 5800 K is incident on this material, determine the fractions of the irradiation that are transmitted, reflected and absorbed by the material.

[8 marks]

…6/-

[c] *If the temperature of this material is 350 K, determine the emissivity,* ε_λ.

[7 marks]

[d] *Determine the net heat flux by radiation to the material.*

[5 marks]

5. [a] Suatu pemeluwap direkabentuk untuk memeluwap 10,000 kg/jam bahan pendingin 12 ($CCl_2 F_2$) pada 37.8°C. Suatu susunan segiempat sama 25 x 25, tiub yang berdiameter 12 mm digunakan dengan air mengalir ke dalam tiub-tiub bagi mengekalkan suhu dinding pada 32.2°C. Kirakan panjang tiub-tiub tersebut. Diberikan:

$h_{fg} = 130.09$ kJ/kg
$\rho = 1276$ kg/m^3
$\nu = 0.193 \times 10^{-6}$ m^2/s
$k = 0.07$ W/m . °C

[15 markah]

[b] Kirakan haba per unit panjang sekiranya bahan pendingin di bahagian [a] dipeluwap di dalam tiub melintang berdiameter 12 mm yang mempunyai halaju wap rendah. Suhu pemeluwapan ialah 32.3°C dan suhu dinding tiub ialah 26.7°C. Diberikan:

$h_{fg}' = h_{fg} + 0.68\, c\, \Delta T.$
di mana $c = 984$ J/kg°C

[10 markah]

5. *[a]* *A condenser is to be designed to condense 10,000 kg/hr of refrigerant 12 ($CCl_2 F_2$) at 37.8°C. A square 25 by 25 array of 12 mm diameter tubes is to be used, with water flow inside the tubes maintaining the wall temperature at 32.2°C. Calculate the length of the tubes. Given:*

$h_{fg} = 130.09$ *kJ/kg*
$\rho = 1276$ *kg/m*^{3}
$\nu = 0.193 \times 10^{-6}$ *m*^{2}*/s*
$k = 0.07$ *W/m . °C*

[15 marks]

[b] *Calculate the heat per unit length if the refrigerant in part [a] is condensed inside a horizontal 12 mm diameter tube at a low vapor velocity. The condensing temperature is 32.3°C and the tube wall is at 26.7°C. Given:*

$h_{fg}' = h_{fg} + 0.68\, c\, \Delta T.$
where $c = 984$ *J/kg°C*

[10 marks]

...7/-

6. [a] Suatu pemeluwap yang bersaiz besar direkabentuk untuk mengeluarkan 800 MW tenaga daripada pemeluwapan stim pada tekanan 1 atm. Bagi mencapai tujuan ini, air penyejuk memasuki pemeluwap pada 25°C dan meninggalkan pemeluwap pada 30°C. Pekali pemindahan haba keseluruhan (u) ialah 2000 $W/m^2.°C$. Kirakan keluasan penukar haba yang diperlukan.

[10 markah]

[b] Sekiranya kadar pengaliran air di bahagian [a] di atas dikurangkan kepada separuh daripada nilai reka bentuk. Berapakah kadar pemeluwapan stim (dalam kg/jam) di bawah syarat-syarat seperti di atas sekiranya U dikekalkan? Diberikan:

$h_{fg} = 2.255 \times 10^6$ J/kg

[15 markah]

6. [a] A large condenser is designed to remove 800 MW of energy from condensing steam at 1 atm pressure. To accomplish this task, cooling water enters the condenser at 25°C and leaves at 30°C. The overall heat transfer coefficient (u) is 2000 $W/m^2.°C$. Calculate the area required for the heat exchanger.

[10 marks]

[b] Suppose the water flow rate for part [a] above is reduced in half from the design value. What will be the steam condensation rate (in kg/hr) under these conditions if U remains the same? Given :

$h_{fg} = 2.255 \times 10^6$ J/kg

[15 marks]

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Lampiran

Convection heat transfer equations

1. $Nu = 0.332\,(Pr)^{1/3}\,(Re)^{1/2}$

2. $Nu = 0.027\,(Re)^{0.8}\,(Pr)^{1/3}\,(\mu / \mu w)^{0.14}$

3. Rayleigh Number $Ra = g\ \beta\,(Tw - T\infty)\,\delta^3\,Pr / \upsilon^2$ Where $g = 9.8$

$Nu = C\,(Gr\ .\ Pr)^m$ Where $C = 0.15$ and $m = 1/3$

Grashof equation $Gr = g\ \beta\ (T_w - T_\infty)\,\delta^3 / \upsilon^2$

4. $K_e / K = C\,(Ra)^n\,(L / \delta)^m$ where $C = 0.13$ $n = 0.3$ $m = 0.0$
For any value of Ra

Air gas constant = 287 J /kg K
Universal gas constant = 8314.5 J/kg mol K
Helium Molecular wt. = 4

Table for Helium
Table for Ethylene glycol
Table for oil
Table for oxygen
Table for air

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Table Properties of gases at atmospheric pressure.†

Values of μ, k, c_p, and Pr are not strongly pressure-dependent for He, H_2, O_2, and N_2 and may be used over a fairly wide range of pressures

T, K	ρ kg/m³	c_p kJ/kg · °C	μ, kg/m · s	ν, m²/s	k W/m · °C	α, m²/s	Pr
Helium							
144	0.3379	5.200	125.5 × 10⁻⁷	37.11 × 10⁻⁶	0.0928	0.5275 × 10⁻⁴	0.70
200	0.2435	5.200	156.6	64.38	0.1177	0.9288	0.694
255	0.1906	5.200	181.7	95.50	0.1357	1.3675	0.70
366	0.13280	5.200	230.5	173.6	0.1691	2.449	0.71
477	0.10204	5.200	275.0	269.3	0.197	3.716	0.72
589	0.08282	5.200	311.3	375.8	0.225	5.215	0.72
700	0.07032	5.200	347.5	494.2	0.251	6.661	0.72
800	0.06023	5.200	381.7	634.1	0.275	8.774	0.72
Hydrogen							
150	0.16371	12.602	5.595 × 10⁻⁶	34.18 × 10⁻⁶	0.0981	0.475 × 10⁻⁴	0.718
200	0.12270	13.540	6.813	55.53	0.1282	0.772	0.719
250	0.09819	14.059	7.919	80.64	0.1561	1.130	0.713
300	0.08185	14.314	8.963	109.5	0.182	1.554	0.706
350	0.07016	14.436	9.954	141.9	0.206	2.031	0.697
400	0.06135	14.491	10.864	177.1	0.228	2.568	0.690
450	0.05462	14.499	11.779	215.6	0.251	3.164	0.682
500	0.04918	14.507	12.636	257.0	0.272	3.817	0.675
550	0.04469	14.532	13.475	301.6	0.292	4.516	0.668
600	0.04085	14.537	14.285	349.7	0.315	5.306	0.664
700	0.03492	14.574	15.89	455.1	0.351	6.903	0.659
800	0.03060	14.675	17.40	569	0.384	8.563	0.664
900	0.02723	14.821	18.78	690	0.412	10.217	0.676
Oxygen							
150	2.6190	0.9178	11.490 × 10⁻⁶	4.387 × 10⁻⁶	0.01367	0.05688 × 10⁻⁴	0.773
200	1.9559	0.9131	14.850	7.593	0.01824	0.10214	0.745
250	1.5618	0.9157	17.87	11.45	0.02259	0.15794	0.725
300	1.3007	0.9203	20.63	15.86	0.02676	0.22353	0.709
350	1.1133	0.9291	23.16	20.80	0.03070	0.2968	0.702
400	0.9755	0.9420	25.54	26.18	0.03461	0.3768	0.695
450	0.8682	0.9567	27.77	31.99	0.03828	0.4609	0.694
500	0.7801	0.9722	29.91	38.34	0.04173	0.5502	0.697
550	0.7096	0.9881	31.97	45.05	0.04517	0.641	0.700
Nitrogen							
200	1.7108	1.0429	12.947 × 10⁻⁶	7.568 × 10⁻⁶	0.01824	0.10224 × 10⁻⁴	0.747
300	1.1421	1.0408	17.84	15.63	0.02620	0.22044	0.713
400	0.8538	1.0459	21.98	25.74	0.03335	0.3734	0.691
500	0.6824	1.0555	25.70	37.66	0.03984	0.5530	0.684
600	0.5687	1.0756	29.11	51.19	0.04580	0.7486	0.686
700	0.4934	1.0969	32.13	65.13	0.05123	0.9466	0.691
800	0.4277	1.1225	34.84	81.46	0.05609	1.1685	0.700
900	0.3796	1.1464	37.49	91.06	0.06070	1.3946	0.711
1000	0.3412	1.1677	40.00	117.2	0.06475	1.6250	0.724
1100	0.3108	1.1857	42.28	136.0	0.06850	1.8571	0.736
1200	0.2851	1.2037	44.50	156.1	0.07184	2.0932	0.748

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Table Properties of gases at atmospheric pressure.[†] (*Continued*)

Values of μ, k, c_p, and Pr are not strongly pressure-dependent for He, H_2, O_2, and N_2 and may be used over a fairly wide range of pressures

T, K	ρ kg/m³	c_p kJ/kg·°C	μ, kg/m·s	ν, m²/s	k W/m·°C	α, m²/s	Pr
Carbon dioxide							
220	2.4733	0.783	11.105×10^{-6}	4.490×10^{-6}	0.010805	0.05920×10^{-4}	0.818
250	2.1657	0.804	12.590	5.813	0.012884	0.07401	0.793
300	1.7973	0.871	14.958	8.321	0.016572	0.10588	0.770
350	1.5362	0.900	17.205	11.19	0.02047	0.14808	0.755
400	1.3424	0.942	19.32	14.39	0.02461	0.19463	0.738
450	1.1918	0.980	21.34	17.90	0.02897	0.24813	0.721
500	1.0732	1.013	23.26	21.67	0.03352	0.3084	0.702
550	0.9739	1.047	25.08	25.74	0.03821	0.3750	0.685
600	0.8938	1.076	26.83	30.02	0.04311	0.4483	0.668
Ammonia, NH_3							
273	0.7929	2.177	9.353×10^{-6}	1.18×10^{-5}	0.0220	0.1308×10^{-4}	0.90
323	0.6487	2.177	11.035	1.70	0.0270	0.1920	0.88
373	0.5590	2.236	12.886	2.30	0.0327	0.2619	0.87
423	0.4934	2.315	14.672	2.97	0.0391	0.3432	0.87
473	0.4405	2.395	16.49	3.74	0.0467	0.4421	0.84
Water vapor							
380	0.5863	2.060	12.71×10^{-6}	2.16×10^{-5}	0.0246	0.2036×10^{-4}	1.060
400	0.5542	2.014	13.44	2.42	0.0261	0.2338	1.040
450	0.4902	1.980	15.25	3.11	0.0299	0.307	1.010
500	0.4405	1.985	17.04	3.86	0.0339	0.387	0.996
550	0.4005	1.997	18.84	4.70	0.0379	0.475	0.991
600	0.3652	2.026	20.67	5.66	0.0422	0.573	0.986
650	0.3380	2.056	22.47	6.64	0.0464	0.666	0.995
700	0.3140	2.085	24.26	7.72	0.0505	0.772	1.000
750	0.2931	2.119	26.04	8.88	0.0549	0.883	1.005
800	0.2739	2.152	27.86	10.20	0.0592	1.001	1.010
850	0.2579	2.186	29.69	11.52	0.0637	1.130	1.019

[†]Adapted to SI units from E. R. G. Eckert and R. M. Drake, *Heat and Mass Transfer*, 2nd ed. New York: McGraw-Hill, 1959.

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Table Properties of saturated liquids.[†]

T, °C	ρ kg/m³	c_p kJ/kg · °C	ν, m²/s	k W/m · °C	α, m²/s	Pr	β, K⁻¹
			Ammonia, NH_3				
−50	703.69	4.463	0.435 × 10⁻⁶	0.547	1.742 × 10⁻⁷	2.60	
−40	691.68	4.467	0.406	0.547	1.775	2.28	
−30	679.34	4.476	0.387	0.549	1.801	2.15	
−20	666.69	4.509	0.381	0.547	1.819	2.09	
−10	653.55	4.564	0.378	0.543	1.825	2.07	
0	640.10	4.635	0.373	0.540	1.819	2.05	
10	626.16	4.714	0.368	0.531	1.801	2.04	
20	611.75	4.798	0.359	0.521	1.775	2.02	2.45 × 10⁻³
30	596.37	4.890	0.349	0.507	1.742	2.01	
40	580.99	4.999	0.340	0.493	1.701	2.00	
50	564.33	5.116	0.330	0.476	1.654	1.99	
			Carbon dioxide, CO_2				
−50	1,156.34	1.84	0.119 × 10⁻⁶	0.0855	0.4021 × 10⁻⁷	2.96	
−40	1,117.77	1.88	0.118	0.1011	0.4810	2.46	
−30	1,076.76	1.97	0.117	0.1116	0.5272	2.22	
−20	1,032.39	2.05	0.115	0.1151	0.5445	2.12	
−10	983.38	2.18	0.113	0.1099	0.5133	2.20	
0	926.99	2.47	0.108	0.1045	0.4578	2.38	
10	860.03	3.14	0.101	0.0971	0.3608	2.80	
20	772.57	5.0	0.091	0.0872	0.2219	4.10	14.00 × 10⁻³
30	597.81	36.4	0.080	0.0703	0.0279	28.7	
			Sulfur dioxide, SO_2				
−50	1,560.84	1.3595	0.484 × 10⁻⁶	0.242	1.141 × 10⁻⁷	4.24	
−40	1,536.81	1.3607	0.424	0.235	1.130	3.74	
−30	1,520.64	1.3616	0.371	0.230	1.117	3.31	
−20	1,488.60	1.3624	0.324	0.225	1.107	2.93	
−10	1,463.61	1.3628	0.288	0.218	1.097	2.62	
0	1,438.46	1.3636	0.257	0.211	1.081	2.38	
10	1,412.51	1.3645	0.232	0.204	1.066	2.18	
20	1,386.40	1.3653	0.210	0.199	1.050	2.00	1.94 × 10⁻³
30	1,359.33	1.3662	0.190	0.192	1.035	1.83	
40	1,329.22	1.3674	0.173	0.185	1.019	1.70	
50	1,299.10	1.3683	0.162	0.177	0.999	1.61	
			Dichlorodifluoromethane (Freon-12), CCl_2F_2				
−50	1,546.75	0.8750	0.310 × 10⁻⁶	0.067	0.501 × 10⁻⁷	6.2	2.63 × 10⁻³
−40	1,518.71	0.8847	0.279	0.069	0.514	5.4	
−30	1,489.56	0.8956	0.253	0.069	0.526	4.8	
−20	1,460.57	0.9073	0.235	0.071	0.539	4.4	
−10	1,429.49	0.9203	0.221	0.073	0.550	4.0	
0	1,397.45	0.9345	0.214 × 10⁻⁶	0.073	0.557 × 10⁻⁷	3.8	
10	1,364.30	0.9496	0.203	0.073	0.560	3.6	
20	1,330.18	0.9659	0.198	0.073	0.560	3.5	
30	1,295.10	0.9835	0.194	0.071	0.560	3.5	
40	1,257.13	1.0019	0.191	0.069	0.555	3.5	
50	1,215.96	1.0216	0.190	0.067	0.545	3.5	

...5/-