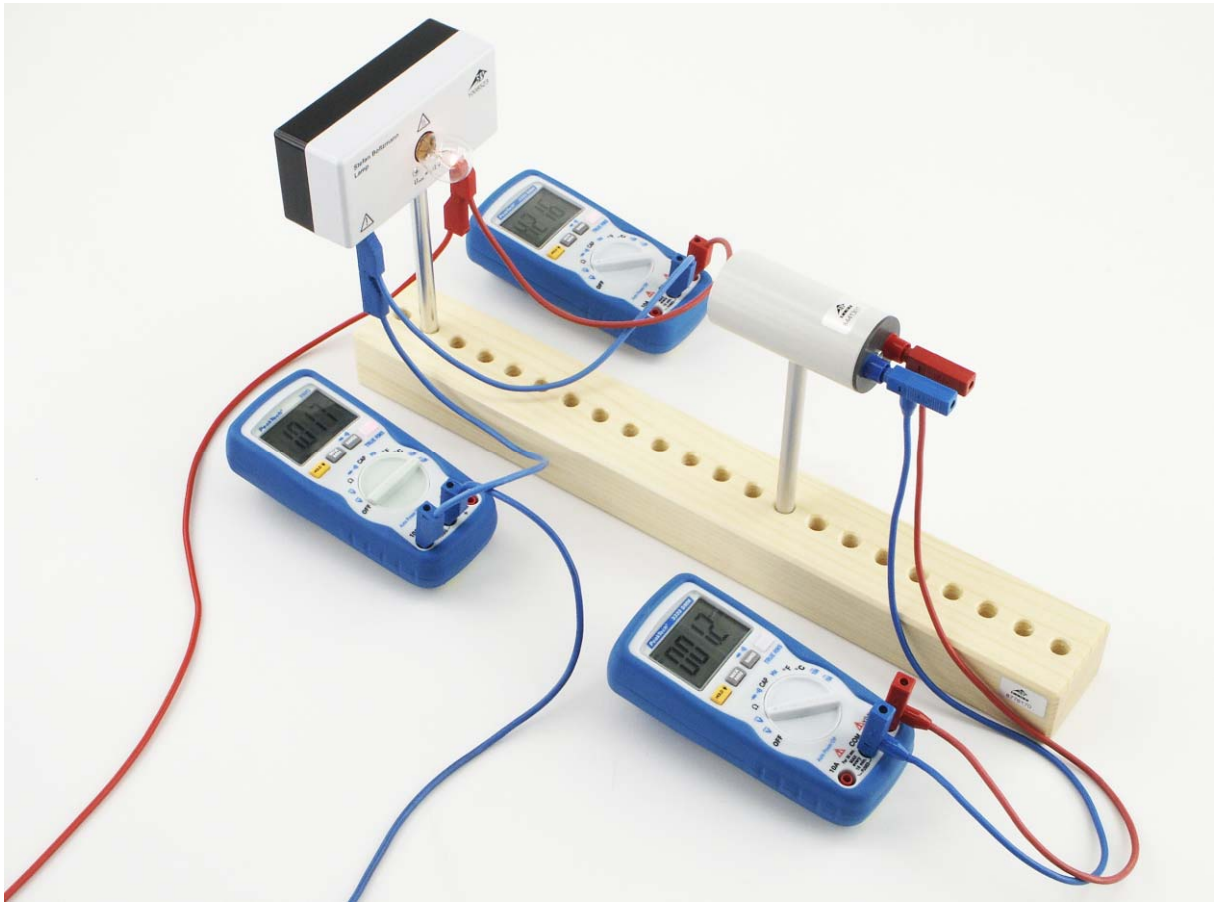
3B SCIENTIFIC® PHYSICS

...going one step further

Stefan-Boltzmann Lamp 1008523

Instruction manual

11/12 NF/ALF



1. Safety instructions

The Stefan-Boltzmann lamp conforms to the safety stipulations for electrical measuring, control and laboratory instruments as specified in DIN EN 61010 part 1. It is intended for use in dry rooms suitable for the operation of electrical equipment.

Safe operation of the equipment can be assured as long as it is used as stipulated. However, safety cannot be guaranteed if the equipment is used incorrectly or handled without due care and attention.

Caution: When in operation, the lamp can become very hot. There is then a risk of burns if it is touched. This can also result in greasy residues being burned onto the lamp.

- Do not touch the lamp with your fingers.
- Allow the lamp to cool after the experiment has been completed.

Note:

Applying a voltage of more than 13 V to the terminals is likely to destroy the filament.

- Never apply a voltage higher than 13 V across the two 4-mm sockets.

2. Description

The Stefan-Boltzmann lamp is a high temperature source with a tungsten filament. It is designed to produce thermal radiation and for investigating how such radiation depends on the temperature. It can be used to confirm the Stefan-Boltzmann law, as stated in the following equation:

$$P = \varepsilon \cdot \sigma \cdot A \cdot T^4$$

P in this equation is the power radiated, T is the absolute temperature of the filament, A is the area of the filament's surface, σ is the Stefan-Boltzmann constant and ε is a dimensionless constant of a value between 0 and 1. The temperature of the lamp can be determined from the resistance of the filament.

The filament represents a good approximation of a point source of heat radiation and is thus highly suitable for investigating the inverse square law for heat radiation.

3. Equipment

1 Stand rod, 130 mm long

1 Stefan-Boltzmann lamp

4. Technical data

Nominal voltage:	12 V DC
Nominal current:	1.75 A
Nominal power:	21 W
Max. operating parameters:	13 V DC/2 A
Maximum temperature of filament:	3600 K
Distance of filament from rod:	25 mm

5. Operation

5.1 Changing bulbs

In order to change the bulb the following equipment is also required:

1 Bulb, 12 V/21 W, socket BA15S

1 Screwdriver

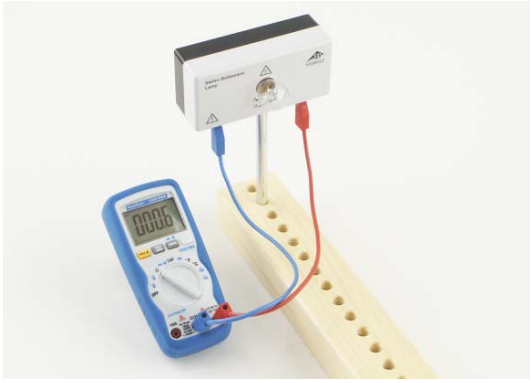
1 Piece of sandpaper

1 Soldering iron

Solder

- Unscrew the back of the housing.
- Unsolder the bulb.
- Sand down the contact surfaces where the wires are to be soldered to the new bulb and tin them with solder.
- Set the bulb in position and solder it in place.
- Test the lamp by applying a voltage of 12 V.
- Screw the housing back together.

5.2 Measurement of filament resistance at room temperature



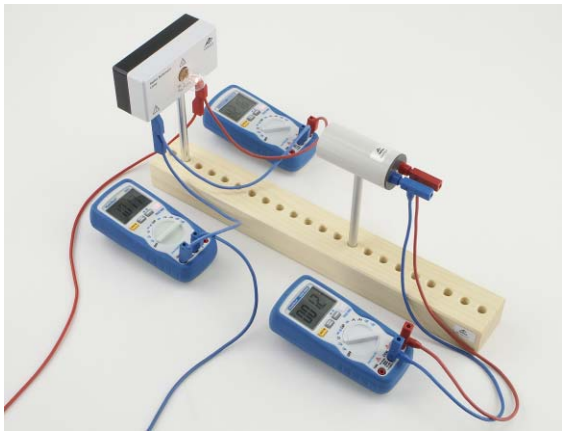
Additionally required:

1 Digital multimeter, P3340	1002785
1 Storage rail	1003034

Safety experiment leads

- Insert one of the measuring leads into the COM socket of the digital multimeter and one into its V Ω mA socket, then short the leads together.
- Select the Ω measuring range, wait for zero to be displayed and then briefly press the REL button.
- Break the contact between the leads and insert them into the sockets of the Stefan-Boltzmann lamp.
- Read off the resistance value R_{ref} and make a note of it.
- Remove the measuring leads.
- Use the multimeter's temperature sensor to measure the ambient temperature T_{ref} in the vicinity of the lamp in Kelvin and make a note of it.

5.3 Measurement of radiant intensity as a function of the temperature of the filament



Additionally required:

1 Storage rail	1003034
1 Thermopile	1000824
3 P3340 digital multimeters	1002785
1 DC power supply, 20 V (@230V)	1003312
or	
1 DC power supply, 20 V (@115V)	1003311
Safety experiment leads	
Stand equipment	

- At the beginning of the experiment, the resistance of the filament and the ambient temperature should be determined as described in section 5.2.
- Next, the thermopile should be connected to the multimeter.
- Set up the Stefan-Boltzmann lamp in front of the thermopile and connect up the DC power supply and multimeters.
- Apply a voltage in steps of 1 V up to a maximum of 12 V and use the thermopile to measure the radiant intensity Φ.
- Measure the voltage V across the lamp and the current I passing through it, then use Ohm's law to calculate the resistance of the filament R.
- Now the values determined, T_{ref}, R_{ref}, R, can be used along with the temperature coefficient of resistance for tungsten $\alpha = 4.4 \cdot 10^{-3} K^{-1}$ to calculate the temperature of the filament by means of the following formula:

$$T = \left(\frac{R - R_{ref}}{\alpha \cdot R_{ref}} \right) + T_{ref}$$

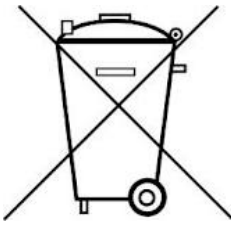
One possible alternative method for determining the temperature T of the filament is to calculate the quotients R/R_{ref} and then use Graph 2 or Table 3 to find the temperature.

Note: In Table 3 the quotient R/R_{ref} is specified for T_{ref} = 300 K and for T_{ref} = 290 K. It is possible to determine the temperature more precisely by interpolating between these two reference values to take account of the actual room temperature.

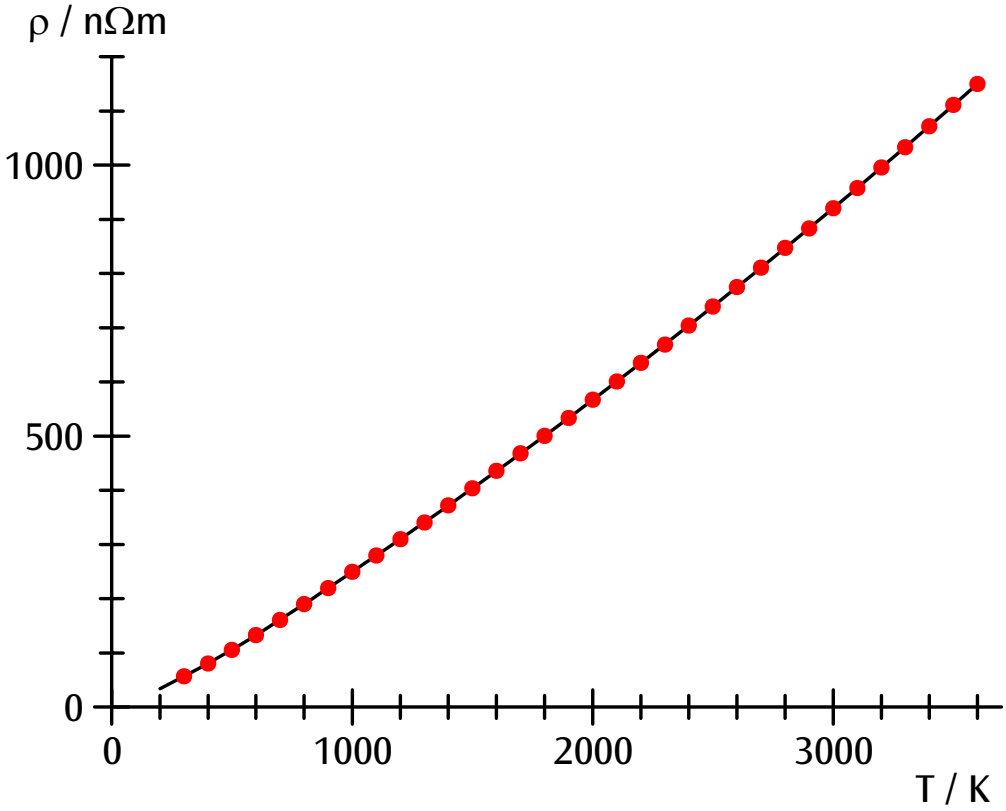
5.4 Evaluation

- To confirm the Stefan-Boltzmann law, plot the measured intensity Φ against T^4, see section 7 Example measurement.

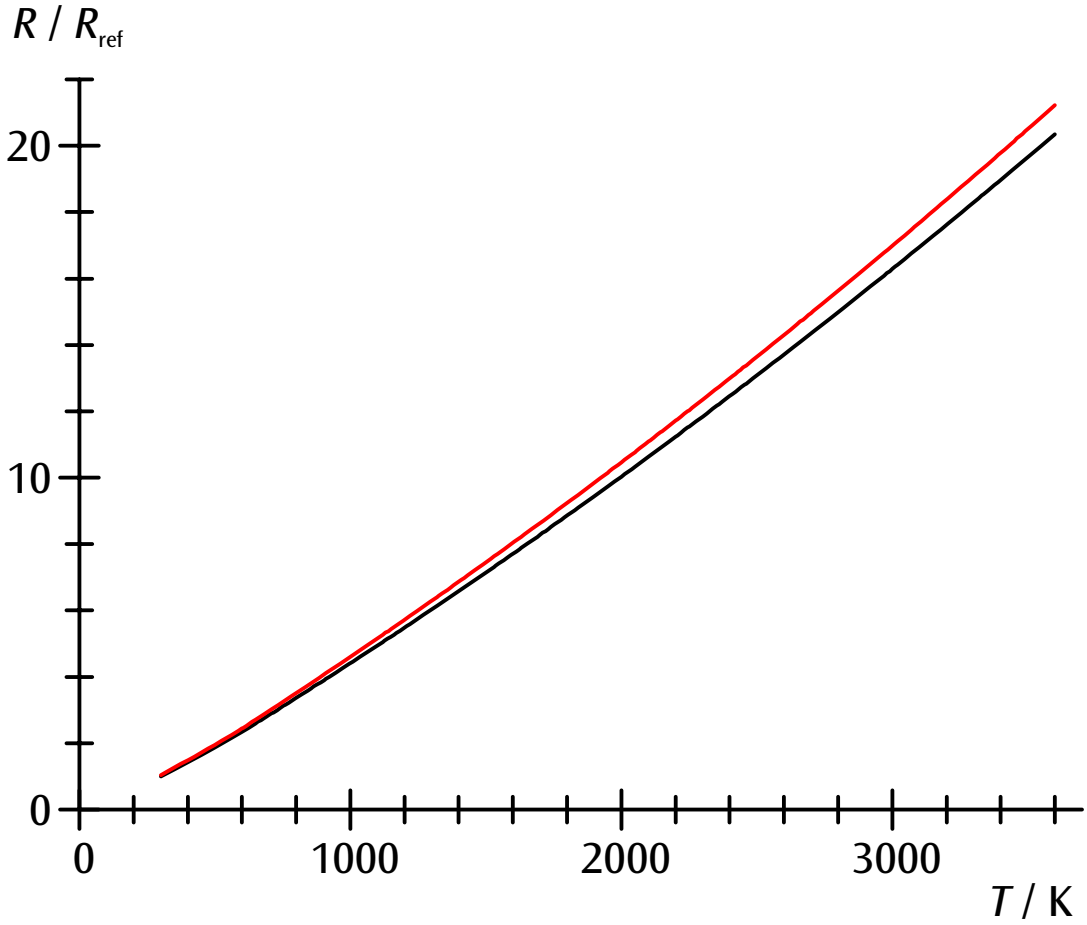
6. Disposal



- Packaging should be disposed of at local recycling centres.
- Should the equipment need to be scrapped, it must not be disposed of in normal household waste. Local regulations for the disposal of electrical equipment should be observed.



Graph 1 Electrical resistivity ρ of tungsten as a function of absolute temperature *T*, cf. Table 3. Curve based on measurements made by Zerda, T.W., Texas Christian University 2001.



Graph 2 Ratio of resistances $R(T)/R_{300\,K}$ (black) or $R(T)/R_{290}$ (red), calculated from the measurements in Graph 1

7. Sample measurements

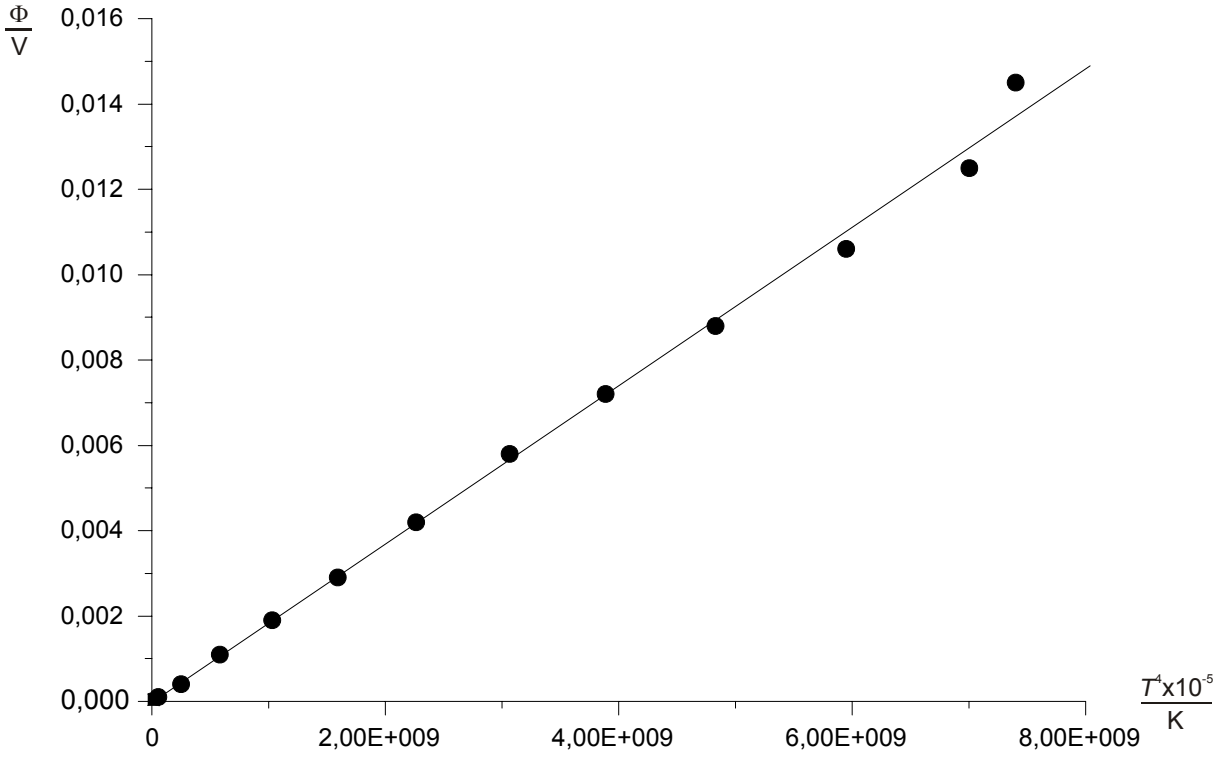
- 1. Measure the ambient temperature T_{ref} and reference resistance R_{ref} for the lamp.
- 2. Measure the voltage V across the lamp, the current through the lamp *I* and the radiant intensity Φ.
- 3. Calculate $R = U/I$.
- 4. Calculate $T = \left(\frac{R - R_{ref}}{\alpha \cdot R_{ref}} \right) + T_{ref}$.
- 5. Plot Φ as a function of T^4.

R_{ref}	0.541 Ω
T_{ref}	297 K

Table 1 Measurements

***U* in V**	***I* in A**	***R* in Ω**	***T* in K**	**Φ in V**
0.00369	0.006	0.615	328	0
1.0502	0.554	1.896	854	0.0001
2.033	0.706	2.879	1259	0.0004
3.012	0.837	3.599	1554	0.0011
4.003	0.958	4.178	1792	0.0019
5.012	1.071	4.679	1998	0.0029
6.017	1.174	5.125	2181	0.0042
7.074	1.276	5.5434	2353	0.0058
8.028	1.362	5.894	2497	0.0072
9.011	1.446	6.232	2636	0.0088
10.088	1.534	6.576	2777	0.0106
11.02	1.607	6.8575	2893	0.0125
11.685	1.68	6.955	2933	0.0145

Table 2 Measurements



Graph 3 Radiant intensity as a function of temperature

$\frac{T}{K}$	$\frac{\rho}{n\Omega m}$	$\frac{R(T)}{R_{300K}}$	$\frac{R(T)}{R_{290K}}$	$\frac{T}{K}$	$\frac{\rho}{n\Omega m}$	$\frac{R(T)}{R_{300K}}$	$\frac{R(T)}{R_{290K}}$	$\frac{T}{K}$	$\frac{\rho}{n\Omega m}$	$\frac{R(T)}{R_{300K}}$	$\frac{R(T)}{R_{290K}}$	$\frac{T}{K}$	$\frac{\rho}{n\Omega m}$	$\frac{R(T)}{R_{300K}}$	$\frac{R(T)}{R_{290K}}$
290	54.17		1.000	710	163.86	2.900	3.025	1130	288.49	5.106	5.325	1550	419.46	7.424	7.743
300	56.50	1.000	1.043	720	166.76	2.951	3.078	1140	291.53	5.160	5.381	1560	422.65	7.481	7.802
310	58.84	1.041	1.086	730	169.65	3.003	3.132	1150	294.58	5.214	5.438	1570	425.85	7.537	7.861
320	61.19	1.083	1.130	740	172.55	3.054	3.185	1160	297.63	5.268	5.494	1580	429.06	7.594	7.920
330	63.56	1.125	1.173	750	175.46	3.105	3.239	1170	300.69	5.322	5.550	1590	432.26	7.651	7.979
340	65.93	1.167	1.217	760	178.37	3.157	3.292	1180	303.75	5.376	5.607	1600	435.47	7.707	8.038
350	68.33	1.209	1.261	770	181.28	3.208	3.346	1190	306.81	5.430	5.663	1610	438.69	7.764	8.098
360	70.73	1.252	1.306	780	184.19	3.260	3.400	1200	309.87	5.484	5.720	1620	441.90	7.821	8.157
370	73.14	1.295	1.350	790	187.11	3.312	3.454	1210	312.94	5.539	5.777	1630	445.13	7.878	8.217
380	75.57	1.338	1.395	800	190.03	3.363	3.508	1220	316.02	5.593	5.833	1640	448.35	7.935	8.276
390	78.02	1.381	1.440	810	192.96	3.415	3.562	1230	319.09	5.648	5.890	1650	451.58	7.992	8.336
400	80.47	1.424	1.485	820	195.89	3.467	3.616	1240	322.18	5.702	5.947	1660	454.81	8.050	8.395
410	82.94	1.468	1.531	830	198.82	3.519	3.670	1250	325.26	5.757	6.004	1670	458.05	8.107	8.455
420	85.42	1.512	1.577	840	201.76	3.571	3.724	1260	328.35	5.811	6.061	1680	461.28	8.164	8.515
430	87.91	1.556	1.623	850	204.70	3.623	3.779	1270	331.44	5.866	6.118	1690	464.53	8.222	8.575
440	90.42	1.600	1.669	860	207.64	3.675	3.833	1280	334.53	5.921	6.175	1700	467.77	8.279	8.635
450	92.94	1.645	1.716	870	210.59	3.727	3.887	1290	337.63	5.976	6.232	1710	471.02	8.337	8.695
460	95.47	1.690	1.762	880	213.54	3.779	3.942	1300	340.73	6.031	6.290	1720	474.28	8.394	8.755
470	98.02	1.735	1.809	890	216.50	3.832	3.996	1310	343.84	6.086	6.347	1730	477.53	8.452	8.815
480	100.57	1.780	1.857	900	219.45	3.884	4.051	1320	346.95	6.141	6.404	1740	480.79	8.510	8.875
490	103.15	1.826	1.904	910	222.42	3.937	4.106	1330	350.06	6.196	6.462	1750	484.06	8.567	8.935
500	105.73	1.871	1.952	920	225.38	3.989	4.160	1340	353.18	6.251	6.519	1760	487.33	8.625	8.996
510	108.33	1.917	2.000	930	228.35	4.042	4.215	1350	356.30	6.306	6.577	1770	490.60	8.683	9.056
520	110.93	1.963	2.048	940	231.32	4.094	4.270	1360	359.42	6.361	6.635	1780	493.87	8.741	9.116
530	113.56	2.010	2.096	950	234.30	4.147	4.325	1370	362.55	6.417	6.692	1790	497.15	8.799	9.177
540	116.19	2.056	2.145	960	237.28	4.200	4.380	1380	365.68	6.472	6.750	1800	500.43	8.857	9.238
550	118.84	2.103	2.194	970	240.26	4.252	4.435	1390	368.82	6.528	6.808	1810	503.72	8.915	9.298
560	121.50	2.150	2.243	980	243.25	4.305	4.490	1400	371.95	6.583	6.866	1820	507.01	8.974	9.359
570	124.17	2.198	2.292	990	246.24	4.358	4.545	1410	375.10	6.639	6.924	1830	510.30	9.032	9.420
580	126.86	2.245	2.342	1000	249.23	4.411	4.601	1420	378.24	6.695	6.982	1840	513.60	9.090	9.481
590	129.56	2.293	2.392	1010	252.23	4.464	4.656	1430	381.39	6.750	7.040	1850	516.90	9.149	9.541
600	132.27	2.341	2.442	1020	255.23	4.517	4.711	1440	384.54	6.806	7.098	1860	520.20	9.207	9.602
610	135.13	2.392	2.494	1030	258.24	4.571	4.767	1450	387.70	6.862	7.157	1870	523.51	9.266	9.663
620	137.98	2.442	2.547	1040	261.25	4.624	4.822	1460	390.86	6.918	7.215	1880	526.82	9.324	9.725
630	140.85	2.493	2.600	1050	264.26	4.677	4.878	1470	394.02	6.974	7.273	1890	530.13	9.383	9.786
640	143.71	2.544	2.653	1060	267.28	4.731	4.934	1480	397.19	7.030	7.332	1900	533.45	9.442	9.847
650	146.58	2.594	2.706	1070	270.29	4.784	4.989	1490	400.36	7.086	7.390	1910	536.77	9.500	9.908
660	149.45	2.645	2.759	1080	273.32	4.837	5.045	1500	403.53	7.142	7.449	1920	540.10	9.559	9.970
670	152.33	2.696	2.812	1090	276.34	4.891	5.101	1510	406.71	7.198	7.508	1930	543.43	9.618	10.031
680	155.20	2.747	2.865	1100	279.37	4.945	5.157	1520	409.89	7.255	7.566	1940	546.76	9.677	10.093
690	158.09	2.798	2.918	1110	282.41	4.998	5.213	1530	413.08	7.311	7.625	1950	550.10	9.736	10.154
700	160.97	2.849	2.971	1120	285.45	5.052	5.269	1540	416.27	7.368	7.684	1960	553.44	9.795	10.216

T/K	ρ/nΩm	$R(T)/R_{300K}$	$R(T)/R_{290K}$	T/K	ρ/nΩm	$R(T)/R_{300K}$	$R(T)/R_{290K}$	T/K	ρ/nΩm	$R(T)/R_{300K}$	$R(T)/R_{290K}$	T/K	ρ/nΩm	$R(T)/R_{300K}$	$R(T)/R_{290K}$
1970	556.78	9.854	10.278	2380	696.95	12.335	12.865	2790	843.18	14.923	15.564	3200	995.45	17.618	18.375
1980	560.13	9.914	10.339	2390	700.45	12.397	12.930	2800	846.82	14.988	15.631	3210	999.24	17.686	18.445
1990	563.48	9.973	10.401	2400	703.95	12.459	12.994	2810	850.46	15.052	15.699	3220	1003.0	17.753	18.515
2000	566.83	10.032	10.463	2410	707.45	12.521	13.059	2820	854.11	15.117	15.766	3230	1006.8	17.820	18.585
2010	570.19	10.092	10.525	2420	710.95	12.583	13.124	2830	857.77	15.182	15.834	3240	1010.6	17.887	18.655
2020	573.55	10.151	10.587	2430	714.46	12.645	13.188	2840	861.42	15.246	15.901	3250	1014.4	17.954	18.725
2030	576.91	10.211	10.649	2440	717.97	12.707	13.253	2850	865.08	15.311	15.969	3260	1018.2	18.022	18.796
2040	580.28	10.270	10.711	2450	721.49	12.770	13.318	2860	868.75	15.376	16.036	3270	1022.1	18.089	18.866
2050	583.65	10.330	10.774	2460	725.01	12.832	13.383	2870	872.41	15.441	16.104	3280	1025.9	18.157	18.937
2060	587.03	10.390	10.836	2470	728.53	12.894	13.448	2880	876.08	15.506	16.172	3290	1029.7	18.224	19.007
2070	590.41	10.450	10.898	2480	732.06	12.957	13.513	2890	879.76	15.571	16.240	3300	1033.5	18.292	19.078
2080	593.79	10.510	10.961	2490	735.59	13.019	13.578	2900	883.44	15.636	16.307	3310	1037.3	18.360	19.148
2090	597.18	10.569	11.023	2500	739.12	13.082	13.644	2910	887.12	15.701	16.375	3320	1041.2	18.428	19.219
2100	600.57	10.629	11.086	2510	742.66	13.144	13.709	2920	890.80	15.766	16.443	3330	1045.0	18.495	19.290
2110	603.96	10.690	11.149	2520	746.20	13.207	13.774	2930	894.49	15.832	16.511	3340	1048.8	18.563	19.360
2120	607.36	10.750	11.211	2530	749.75	13.270	13.840	2940	898.18	15.897	16.580	3350	1052.7	18.631	19.431
2130	610.76	10.810	11.274	2540	753.30	13.333	13.905	2950	901.88	15.962	16.648	3360	1056.5	18.699	19.502
2140	614.17	10.870	11.337	2550	756.85	13.395	13.971	2960	905.58	16.028	16.716	3370	1060.4	18.767	19.573
2150	617.57	10.930	11.400	2560	760.40	13.458	14.036	2970	909.28	16.093	16.785	3380	1064.2	18.836	19.644
2160	620.99	10.991	11.463	2570	763.96	13.521	14.102	2980	912.99	16.159	16.853	3390	1068.1	18.904	19.716
2170	624.40	11.051	11.526	2580	767.53	13.584	14.168	2990	916.70	16.225	16.921	3400	1071.9	18.972	19.787
2180	627.82	11.112	11.589	2590	771.09	13.648	14.234	3000	920.41	16.290	16.990	3410	1075.8	19.040	19.858
2190	631.24	11.172	11.652	2600	774.66	13.711	14.300	3010	924.13	16.356	17.059	3420	1079.7	19.109	19.929
2200	634.67	11.233	11.715	2610	778.24	13.774	14.366	3020	927.85	16.422	17.127	3430	1083.5	19.177	20.001
2210	638.10	11.294	11.779	2620	781.81	13.837	14.432	3030	931.58	16.488	17.196	3440	1087.4	19.246	20.072
2220	641.53	11.354	11.842	2630	785.39	13.901	14.498	3040	935.31	16.554	17.265	3450	1091.3	19.314	20.144
2230	644.97	11.415	11.906	2640	788.98	13.964	14.564	3050	939.04	16.620	17.334	3460	1095.2	19.383	20.215
2240	648.41	11.476	11.969	2650	792.57	14.028	14.630	3060	942.77	16.686	17.403	3470	1099.0	19.452	20.287
2250	651.85	11.537	12.033	2660	796.16	14.091	14.696	3070	946.51	16.752	17.472	3480	1102.9	19.521	20.359
2260	655.30	11.598	12.096	2670	799.75	14.155	14.763	3080	950.26	16.819	17.541	3490	1106.8	19.589	20.431
2270	658.75	11.659	12.160	2680	803.35	14.219	14.829	3090	954.00	16.885	17.610	3500	1110.7	19.658	20.503
2280	662.21	11.720	12.224	2690	806.95	14.282	14.896	3100	957.75	16.951	17.679	3510	1114.6	19.727	20.574
2290	665.66	11.782	12.288	2700	810.56	14.346	14.962	3110	961.51	17.018	17.748	3520	1118.5	19.796	20.646
2300	669.13	11.843	12.351	2710	814.17	14.410	15.029	3120	965.26	17.084	17.818	3530	1122.4	19.865	20.719
2310	672.59	11.904	12.415	2720	817.78	14.474	15.096	3130	969.02	17.151	17.887	3540	1126.3	19.935	20.791
2320	676.06	11.966	12.479	2730	821.40	14.538	15.162	3140	972.79	17.217	17.957	3550	1130.2	20.004	20.863
2330	679.53	12.027	12.544	2740	825.02	14.602	15.229	3150	976.56	17.284	18.026	3560	1134.1	20.073	20.935
2340	683.01	12.089	12.608	2750	828.64	14.666	15.296	3160	980.33	17.351	18.096	3570	1138.1	20.143	21.008
2350	686.49	12.150	12.672	2760	832.27	14.730	15.363	3170	984.10	17.418	18.166	3580	1142.0	20.212	21.080
2360	689.97	12.212	12.736	2770	835.90	14.795	15.430	3180	987.88	17.485	18.235	3590	1145.9	20.281	21.152
2370	693.46	12.274	12.801	2780	839.54	14.859	15.497	3190	991.66	17.551	18.305	3600	1149.8	20.351	21.225

Table 3 Specific temperature coefficient of resistance ρ for tungsten as a function of absolute temperature T and resistance ratios calculated therefrom: $R(T)/R_{\mathbf{300\ K}}$ or $R(T)/R_{290\ K}$, cf. Graph 1.