Fitting thermal conductivity of air

Find least-squares fit of thermal conductivity to air temperatures. Table from Stephan and Laesecke (1985):

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Table 1. Skeleton table of the recommended data set. Thermal conductivity [mW/(m·K)] of air

T [K] \ p [bar]	1.00	10.00	20.00	30.00	40.00	50.00	60.00	80.00	100.00
70.00	6.59								
80.00	7.53	143.30	144.03	144.73	145.43	146.10	146.77	148.08	149.37
90.00	8.48	128.71	129.65	130.55	131.43	132.29	133.11	134.76	136.33
100.00	9.42	113.23	114.49	115.68	116.85	117.99	119.08	121.19	123.17
120.00	11.27	12.60	14.91	81.74	84.79	87.41	89.72	93.72	97.13
130.00	12.18	13.36	15.10	18.28	61.03	67.80	72.32	78.87	83.84
140.00	13.09	14.15	15.59	17.58	21.13	32.66	48.15	61.73	69.42
160.00	14.87	15.77	16.89	18.20	19.80	21.87	24.65	33.05	42.89
180.00	16.61	17.40	18.33	19.36	20.51	21.81	23.32	27.09	31.94
200.00	18.31	19.01	19.82	20.68	21.61	22.61	23.70	26.19	29.17
220.00	19.97	20.60	21.32	22.07	22.85	23.68	24.56	26.48	28.65
240.00	21.59	22.16	22.81	23.48	24.16	24.88	25.62	27.21	28.94
260.00	23.16	23.69	24.28	24.88	25.50	26.13	26.78	28.15	29.61
280.00	24.70	25.18	25.73	26.28	26.84	27.41	27.99	29.20	30.47
300.00	26.19	26.65	27.16	27.67	28.18	28.70	29.23	30.31	31.44
320.00	27.66	28.08	28.56	29.03	29.51	29.99	30.47	31.46	32.48

Read in .csv file of values for 1 Bar.

```r
tablevals <- read.csv("Lambda_vs_tk.csv", header = TRUE,
                      stringsAsFactors = FALSE)
tablevals
```

TK	Lambda
220	19.97
240	21.59
260	23.16
280	24.70
300	26.19
320	27.66

convert units of conductivity to W/mK from mW/mK

```r
tablevals$Lambda <- tablevals$Lambda / 1000
tablevals
```

TK	Lambda
220	0.01997
240	0.02159
260	0.02316
280	0.02470
300	0.02619
320	0.02766

Do linear regression of thermal conductivity vs air temperature (K)

```r
fit <- lm(Lambda~TK, tablevals)
```

Regression coefficients and statistics

```r
summary(fit)
```

Call: lm(formula = Lambda ~ TK, data = tablevals)

Residuals: 1 2 3 4 5 6 -6.619e-05 1.695e-05 5.010e-05 5.324e-05 6.381e-06 -6.048e-05

Coefficients: Estimate Std. Error t value Pr(>|t|)
(Intercept) 3.131e-03 1.904e-04 16.44 8.02e-05 ***TK 7.684e-05 6.998e-07 109.81 4.12e-08*** — Signif. codes: 0 '' ***0.001*** '' *0.01* '' 0.05 '.' 0.1 '' 1

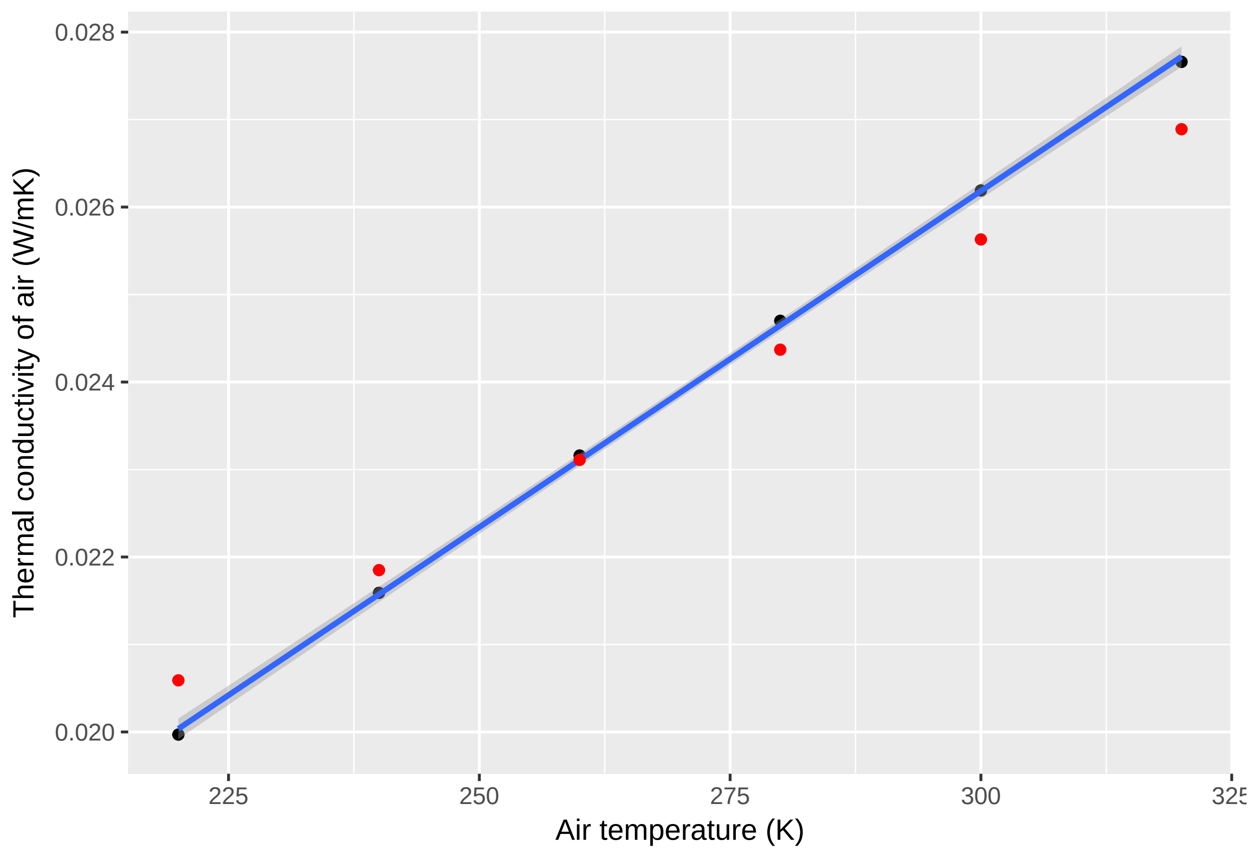
Residual standard error: 5.855e-05 on 4 degrees of freedom Multiple R-squared: 0.9997, Adjusted R-squared: 0.9996 F-statistic: 1.206e+04 on 1 and 4 DF, p-value: 4.124e-08

Calculate CRHM values divided by 10

```r
tablevals$CRHM_divided_by_10 <- (tablevals$TK * 0.00063 + 0.0673) / 10
```

Plot original table data (black points), least-squares fitted line and CRHM values divided by 10 (red points)

```r
ggplot(tablevals, aes(TK, Lambda)) + geom_point(colour = "black") +
  geom_smooth(method = "lm") + xlab("Air temperature (K)") +
  ylab("Thermal conductivity of air (W/mK)") +
  geom_point(aes(TK, CRHM_divided_by_10), colour = "red")
```



Do regression of table values against air temperature in degrees Celsius

```r
tablevals$TC <- tablevals$TK - 273.15
fit2 <- lm(Lambda~TC, tablevals)
```

Regression coefficients and statistics

```r
summary(fit2)
```

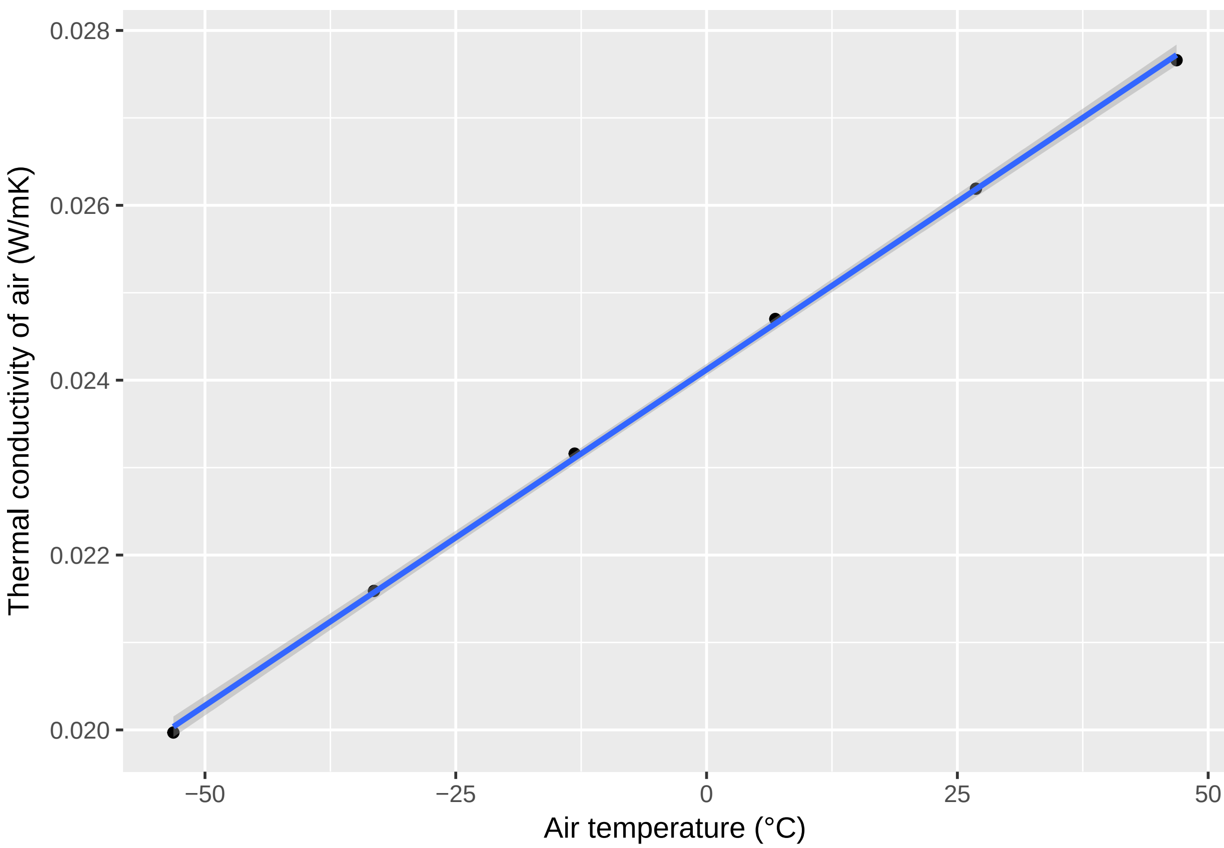
Call: lm(formula = Lambda ~ TC, data = tablevals)

Residuals: 1 2 3 4 5 6 -6.619e-05 1.695e-05 5.010e-05 5.324e-05 6.381e-06 -6.048e-05

Coefficients: Estimate Std. Error t value Pr(>|t|)
(Intercept) 2.412e-02 2.400e-05 1004.9 5.88e-12 ***TC 7.684e-05 6.998e-07 109.8 4.12e-08*** — Signif. codes: 0 ‘’ ***0.001*** ’’ *0.01* ” 0.05 ‘.’ 0.1 ‘’ 1

Residual standard error: 5.855e-05 on 4 degrees of freedom Multiple R-squared: 0.9997, Adjusted R-squared: 0.9996 F-statistic: 1.206e+04 on 1 and 4 DF, p-value: 4.124e-08

```r
ggplot(tablevals, aes(TC, Lambda)) + geom_point(colour = "black") +
  geom_smooth(method = "lm") + xlab("Air temperature (°C)") +
  ylab("Thermal conductivity of air (W/mK)")
```



Use method of Tsilingiris(2007)

```r
KA0 <- -2.276501e-03
KA1 <- 1.2598485e-04
```

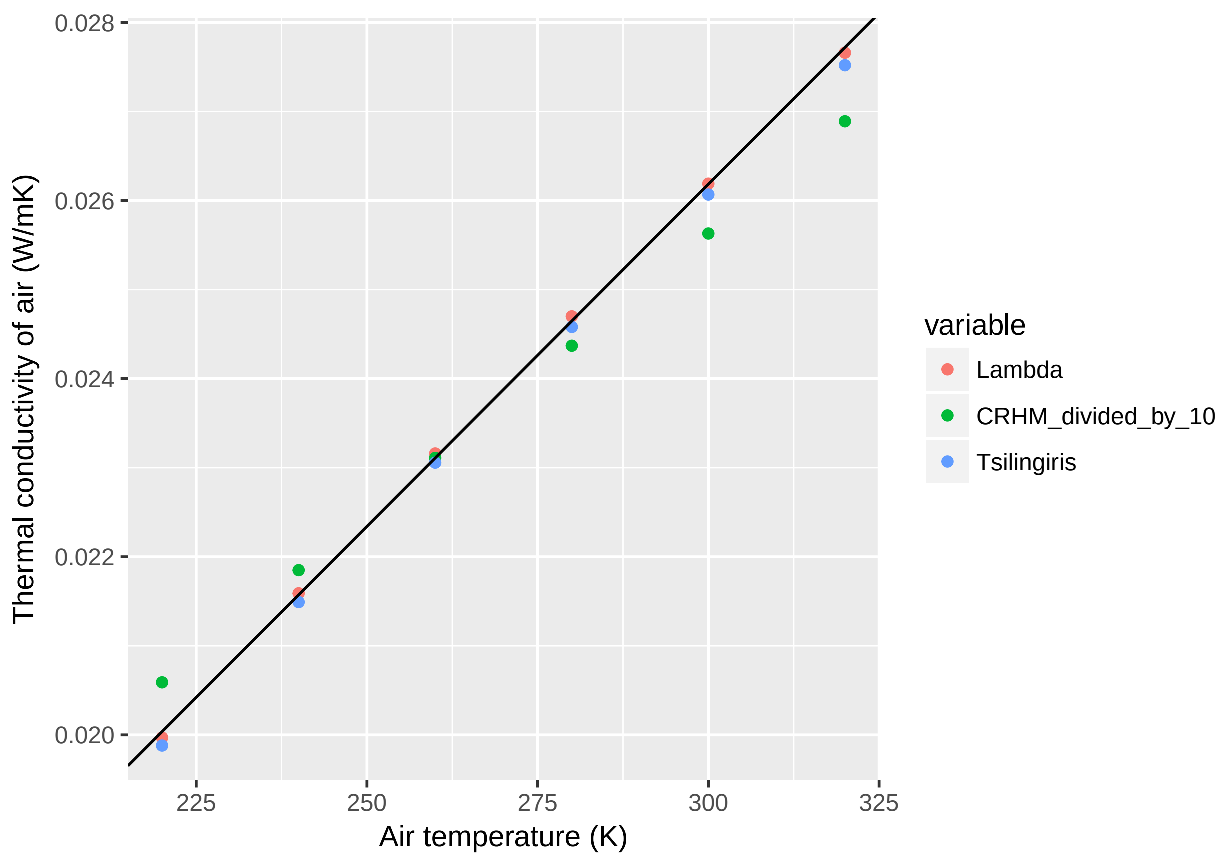
```r
KA2 <- -1.4815235e-07
KA3 <- 1.73550646e-10
KA4 <- -1.066657e-13
KA5 <- 2.47663035e-17

tablevals$Tsilingiris <- KA0 + KA1 * tablevals$TK + KA2 * tablevals$TK^2 +
  KA3 * tablevals$TK^3 + KA4 * tablevals$TK^4 + KA5 * tablevals$TK^5
tablevals <- tablevals[,c("TK", "Lambda", "CRHM_divided_by_10", "Tsilingiris")]
tablevals
```

TK	Lambda	CRHM_divided_by_10	Tsilingiris
220	0.01997	0.02059	0.0198805
240	0.02159	0.02185	0.0214913
260	0.02316	0.02311	0.0230568
280	0.02470	0.02437	0.0245809
300	0.02619	0.02563	0.0260673
320	0.02766	0.02689	0.0275194

Plot original tables values and Tsilingiris. The line is the linear model fitted above.

```r
melted <- melt(tablevals, id.vars = "TK")
ggplot(melted, aes(TK, value, colour = variable)) + geom_point() +
  xlab("Air temperature (K)") +
  ylab("Thermal conductivity of air (W/mK)") +
  geom_abline(slope=coefficients(fit)[[2]], intercept = coefficients(fit)[[1]])
```



So, we can use the linear regression equations, for air temperatures in K or °C with results that are at least as good as the Tsilingiris fifth-order polynomial.