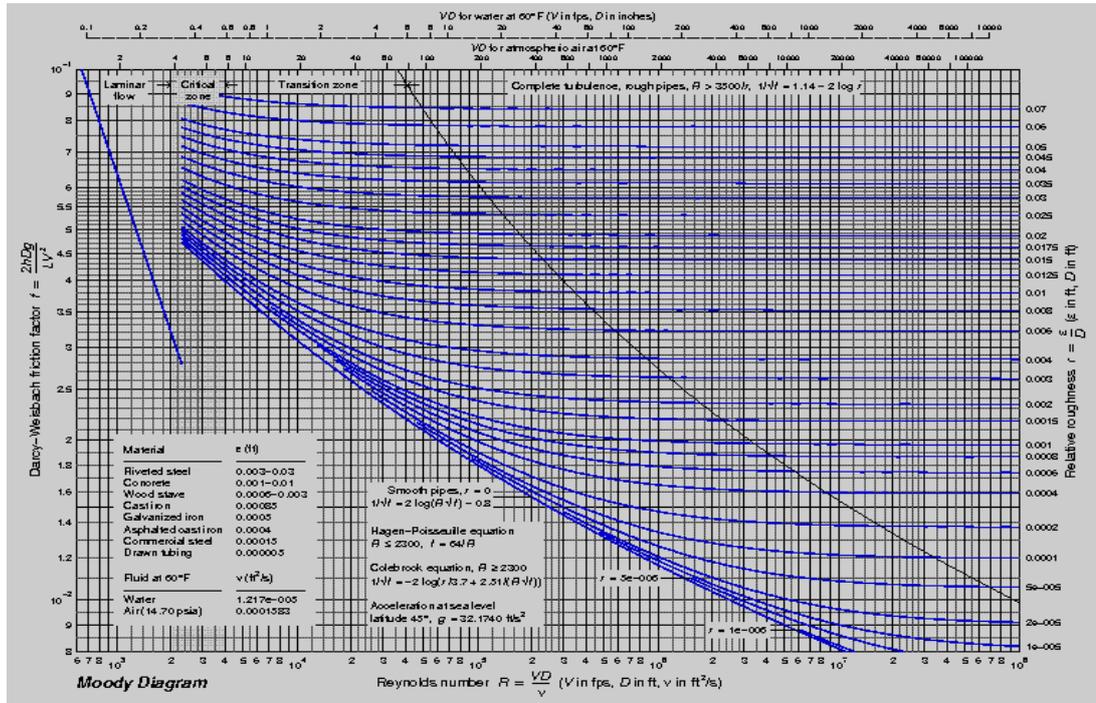


LAMPIRAN

Lampiran 1 : Table Properti Fisik Udara

| T (K) | ρ (kg/m ³) | c_p (kJ/kg · K) | $\mu \cdot 10^7$ (N · s/m ²) | $\nu \cdot 10^6$ (m ² /s) | $k \cdot 10^3$ (W/m · K) | $\alpha \cdot 10^6$ (m ² /s) | Pr |
|------------|--------------------------------|----------------------|---|---|-----------------------------|--|-------|
| 100 | 3.5562 | 1.032 | 71.1 | 2.00 | 9.34 | 2.54 | 0.786 |
| 150 | 2.3364 | 1.012 | 103.4 | 4.426 | 13.8 | 5.84 | 0.758 |
| 200 | 1.7458 | 1.007 | 132.5 | 7.590 | 18.1 | 10.3 | 0.737 |
| 250 | 1.3947 | 1.006 | 159.6 | 11.44 | 22.3 | 15.9 | 0.720 |
| 300 | 1.1614 | 1.007 | 184.6 | 15.89 | 26.3 | 22.5 | 0.707 |
| 350 | 0.9950 | 1.009 | 208.2 | 20.92 | 30.0 | 29.9 | 0.700 |
| 400 | 0.8711 | 1.014 | 230.1 | 26.41 | 33.8 | 38.3 | 0.690 |
| 450 | 0.7740 | 1.021 | 250.7 | 32.39 | 37.3 | 47.2 | 0.686 |
| 500 | 0.6964 | 1.030 | 270.1 | 38.79 | 40.7 | 56.7 | 0.684 |
| 550 | 0.6329 | 1.040 | 288.4 | 45.57 | 43.9 | 66.7 | 0.683 |
| 600 | 0.5804 | 1.051 | 305.8 | 52.69 | 46.9 | 76.9 | 0.685 |
| 650 | 0.5356 | 1.063 | 322.5 | 60.21 | 49.7 | 87.3 | 0.690 |
| 700 | 0.4975 | 1.075 | 338.8 | 68.10 | 52.4 | 98.0 | 0.695 |
| 750 | 0.4643 | 1.087 | 354.6 | 76.37 | 54.9 | 109 | 0.702 |
| 800 | 0.4354 | 1.099 | 369.8 | 84.93 | 57.3 | 120 | 0.709 |
| 850 | 0.4097 | 1.110 | 384.3 | 93.80 | 59.6 | 131 | 0.716 |
| 900 | 0.3868 | 1.121 | 398.1 | 102.9 | 62.0 | 143 | 0.720 |
| 950 | 0.3666 | 1.131 | 411.3 | 112.2 | 64.3 | 155 | 0.723 |
| 1000 | 0.3482 | 1.141 | 424.4 | 121.9 | 66.7 | 168 | 0.726 |
| 1100 | 0.3166 | 1.159 | 449.0 | 141.8 | 71.5 | 195 | 0.728 |
| 1200 | 0.2902 | 1.175 | 473.0 | 162.9 | 76.3 | 224 | 0.728 |
| 1300 | 0.2679 | 1.189 | 496.0 | 185.1 | 82 | 238 | 0.719 |
| 1400 | 0.2488 | 1.207 | 530 | 213 | 91 | 303 | 0.703 |
| 1500 | 0.2322 | 1.230 | 557 | 240 | 100 | 350 | 0.685 |
| 1600 | 0.2177 | 1.248 | 584 | 268 | 106 | 390 | 0.688 |
| 1700 | 0.2049 | 1.267 | 611 | 298 | 113 | 435 | 0.685 |
| 1800 | 0.1935 | 1.286 | 637 | 329 | 120 | 482 | 0.683 |
| 1900 | 0.1833 | 1.307 | 663 | 362 | 128 | 534 | 0.677 |

Lampiran 2 : Diagram Moody



Lampiran 3 : Properties Gas Pada Tekanan Atmosfir

Table A-6 | Properties of gases at atmospheric pressure.[†]

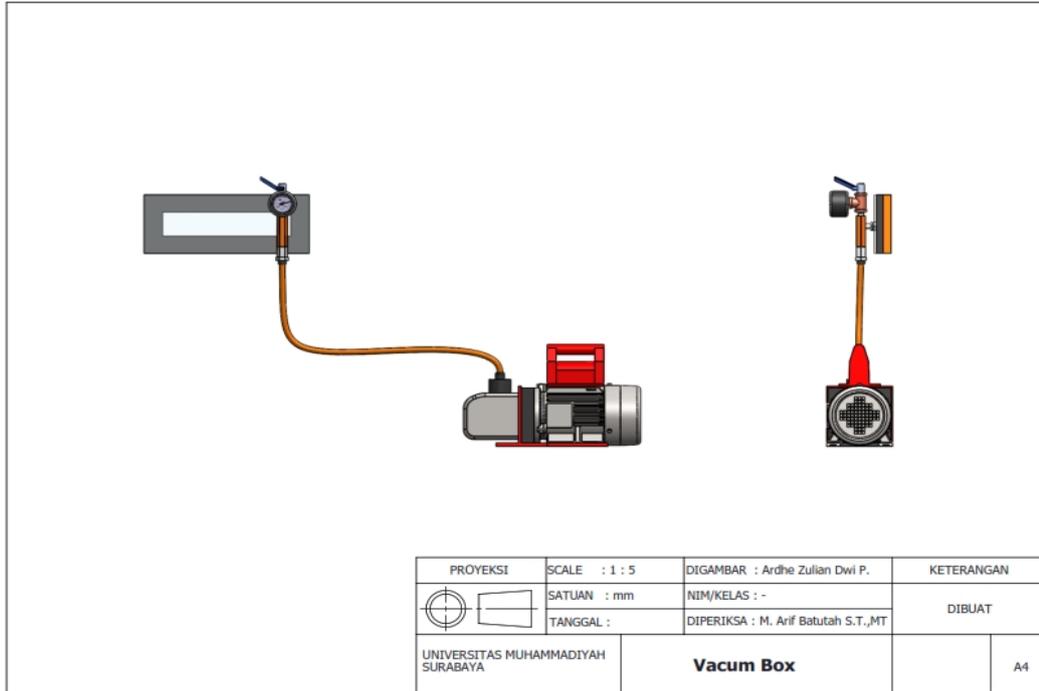
| Values of μ , k , c_p , and Pr are not strongly pressure-dependent for He, H ₂ , O ₂ , and N ₂ and may be used over a fairly wide range of pressures | | | | | | | |
|---|----------------------------|------------------|-------------------------|---------------------------|--------------|------------------------------|-------|
| T, K | ρ , kg/m ³ | c_p , kJ/kg·°C | μ , kg/m·s | ν , m ² /s | k , W/m·°C | α , m ² /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 |

Table A-6 | 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/m ³ | c_p kJ/kg · °C | μ , kg/m · s | ν , m ² /s | k W/m · °C | α , m ² /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, NH₃ | | | | | | | |
| 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.

Lampiran 4 : Detail Gambar Vacuum Box.





Penulis dilahirkan di Kediri, 28 Juli 1994, merupakan anak kedua dari pasangan Alm. Bapak Katiyono dan Ibu. Wiwik Sunami dari 4 bersaudara. Penulis telah menempuh pendidikan formal yaitu, di TK. Dharma Wanita, Ngadiluwih - Kab.Kediri, SDN 1 Ngadiluwih - Kab.Kediri dan SMAK. Santo Augustinus - kota Kediri. lulus dari sekolah menengah

atas tahun 2013, penulis bekerja di salah satu perusahaan swasta di kota Surabaya sekitar satu tahun, dan kemudian penulis mempunyai keinginan untuk melanjutkan pendidikan di tingkat perguruan tinggi di kota Surabaya yaitu, Universitas Muhammadiyah Surabaya dan mengambil Jurusan Teknik Mesin pada tahun 2014. Dan terdaftar dengan NRP/NIM. 2014.1331.118. Penulis selama menempuh pendidikan di perguruan tinggi UM - Surabaya masih tetap bekerja hingga sekarang.