Series 1 (21 February 2025)

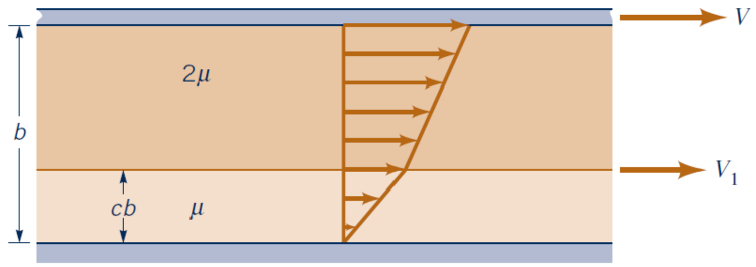
TAs: *Cemre Celikbudak, Soroush Rafiei, Sokratis Anagnostopoulos, Ramin Mohammadi, Ellen Jamil Dagher, Veronika Pak, El Ghali Jaidi, Coline Jeanne Leteurtre*

1.46. The density of oxygen contained in a tank is 2.0 kg/m^3 when the temperature is 25^{o}C. Determine the gage pressure of the gas if the atmospheric pressure is 97 kPa.

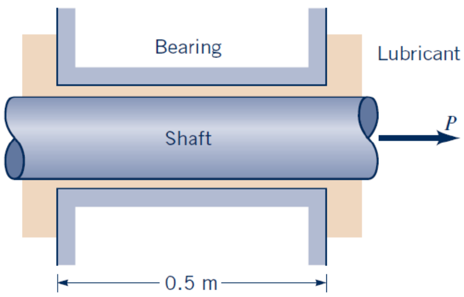
1.63. For air at standard atmospheric pressure the values of the constants that appear in the Sutherland equation (Eq. 1.10) are C=1.458·10^{-6} kg/(m·s·K$^{1/2}$) and S=110.4 K. Use these values to predict the viscosity of air at 10^{o}C and 90^{o}C and compare with values given in Table B.4 in Appendix B (also attached at the end of this exercise series).

$$\mu = \frac{CT^{3/2}}{T+S} \quad (Eq. 1.10)$$

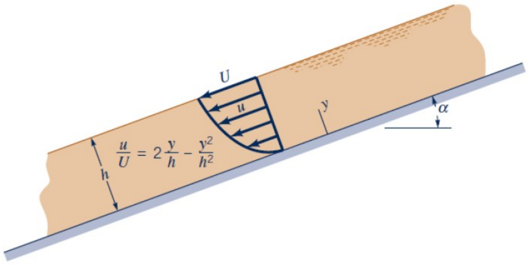
1.69. Two flat plates are oriented parallel above a fixed lower plate as shown in Fig. P1.69. The top plate, located at distance b above the fixed plate, is pulled along with speed V. The other thin plate is located at distance cb, where $0 < c < 1$, above the fixed plate. This plate moves with speed V_1, which is determined by the viscous shear forces imposed on it by the fluids on its top and bottom. The fluid on the top is twice as viscous as that on the bottom. Plot the ratio V_1/V as a function of c for $0 < c < 1$.



1.72. A 25-mm-diameter shaft is pulled through a cylindrical bearing as shown in Fig. P1.72. The lubricant that fills the 0.3-mm gap between the shaft and bearing is an oil having a kinematic viscosity of 8.0 x 10^{-4} m^2/s and a specific gravity of 0.91. Determine the force P required to pull the shaft at a velocity of 3 m/s. Assume the velocity distribution in the gap is linear.



1.76. A thin layer of glycerin flows down an inclined, wide plate with the velocity distribution shown in Fig. P1.76. For h = 0.75 cm and a = 20°, determine the surface velocity, U. Note that for equilibrium, the component of weight acting parallel to the plate surface must be balanced by the shearing force developed along the plate surface. In your analysis assume a unit plate width.



1.81. The viscosity of liquids can be measured through the use of a rotating cylinder viscometer of the type illustrated in Fig. P1.81. In this device the outer cylinder is fixed and the inner cylinder is rotated with an angular velocity, ω. The torque, T, required to develop ω is measured and the viscosity is calculated from these two measurements. (**a**) Develop an equation relating μ, ω, T, ℓ, R_o and R_i. Neglect end effects and assume the velocity distribution in the gap is linear. (**b**) The following torque-angular velocity data were obtained with a rotating cylinder viscometer of the type discussed in part (a).

T (N. m)	17.8	35.3	53.6	71.5	87.9	106.5
ω (rad. s^{-1})	1.0	2.0	3.0	4.0	5.0	6.0

For this viscometer R_o = 6.35 cm, R_i = 6.22 cm and ℓ = 12.7 cm. Make use of these data and a standard curve-fitting program to determine the viscosity of the liquid contained in the viscometer.

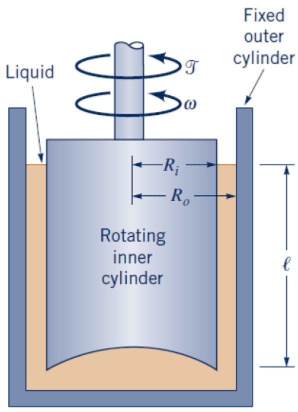


Table B.4

Physical Properties of Air at Standard Atmospheric Pressure (SI Units)[a]

Temperature (°C)	Density, ρ (kg/m^3)	Specific Weight[b], γ (N/m^3)	Dynamic Viscosity, μ (N·s/m^2)	Kinematic Viscosity, ν (m^2/s)	Specific Heat Ratio, k (—)	Speed of Sound, c (m/s)
−40	1.514	14.85	1.57 E − 5	1.04 E − 5	1.401	306.2
−20	1.395	13.68	1.63 E − 5	1.17 E − 5	1.401	319.1
0	1.292	12.67	1.71 E − 5	1.32 E − 5	1.401	331.4
5	1.269	12.45	1.73 E − 5	1.36 E − 5	1.401	334.4
10	1.247	12.23	1.76 E − 5	1.41 E − 5	1.401	337.4
15	1.225	12.01	1.80 E − 5	1.47 E − 5	1.401	340.4
20	1.204	11.81	1.82 E − 5	1.51 E − 5	1.401	343.3
25	1.184	11.61	1.85 E − 5	1.56 E − 5	1.401	346.3
30	1.165	11.43	1.86 E − 5	1.60 E − 5	1.400	349.1
40	1.127	11.05	1.87 E − 5	1.66 E − 5	1.400	354.7
50	1.109	10.88	1.95 E − 5	1.76 E − 5	1.400	360.3
60	1.060	10.40	1.97 E − 5	1.86 E − 5	1.399	365.7
70	1.029	10.09	2.03 E − 5	1.97 E − 5	1.399	371.2
80	0.9996	9.803	2.07 E − 5	2.07 E − 5	1.399	376.6
90	0.9721	9.533	2.14 E − 5	2.20 E − 5	1.398	381.7
100	0.9461	9.278	2.17 E − 5	2.29 E − 5	1.397	386.9
200	0.7461	7.317	2.53 E − 5	3.39 E − 5	1.390	434.5
300	0.6159	6.040	2.98 E − 5	4.84 E − 5	1.379	476.3
400	0.5243	5.142	3.32 E − 5	6.34 E − 5	1.368	514.1
500	0.4565	4.477	3.64 E − 5	7.97 E − 5	1.357	548.8
1000	0.2772	2.719	5.04 E − 5	1.82 E − 4	1.321	694.8

[a]Based on data from R. D. Blevins, *Applied Fluid Dynamics Handbook*, Van Nostrand Reinhold Co., Inc., New York, 1984.

[b]Density and specific weight are related through the equation $\gamma = \rho g$. For this table $g = 9.807$ m/s^2.