Table

1. Continuity equation in Cartesian coordinates:

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho v_x)+\frac{\partial}{\partial y}(\rho v_y)+\frac{\partial}{\partial z}(\rho v_z)=0$$

2. Navier-Stokes equation in Cartesian coordinates:

$$\rho\left(\frac{\partial v_x}{\partial t}+v_x\frac{\partial v_x}{\partial x}+v_y\frac{\partial v_x}{\partial y}+v_z\frac{\partial v_x}{\partial z}\right)=-\frac{\partial P}{\partial x}+\mu\left(\frac{\partial^2 v_x}{\partial x^2}+\frac{\partial^2 v_x}{\partial y^2}+\frac{\partial^2 v_x}{\partial z^2}\right)+\rho g_x$$

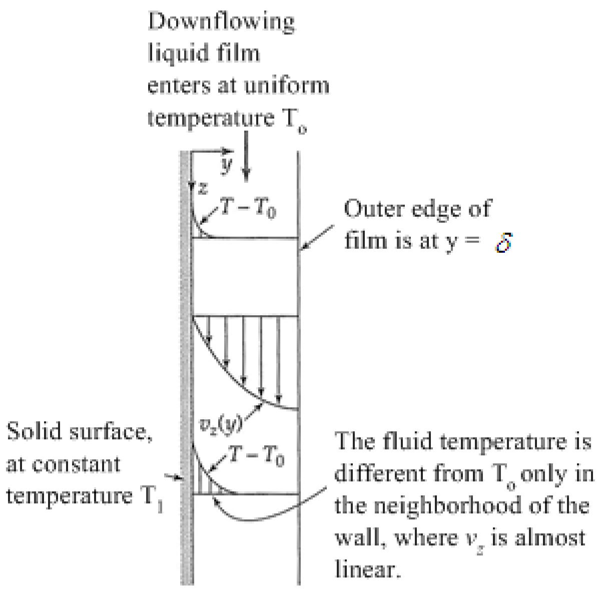
$$\rho\left(\frac{\partial v_y}{\partial t}+v_x\frac{\partial v_y}{\partial x}+v_y\frac{\partial v_y}{\partial y}+v_z\frac{\partial v_y}{\partial z}\right)=-\frac{\partial P}{\partial y}+\mu\left(\frac{\partial^2 v_y}{\partial x^2}+\frac{\partial^2 v_y}{\partial y^2}+\frac{\partial^2 v_y}{\partial z^2}\right)+\rho g_y$$

$$\rho\left(\frac{\partial v_z}{\partial t}+v_x\frac{\partial v_z}{\partial x}+v_y\frac{\partial v_z}{\partial y}+v_z\frac{\partial v_z}{\partial z}\right)=-\frac{\partial P}{\partial z}+\mu\left(\frac{\partial^2 v_z}{\partial x^2}+\frac{\partial^2 v_z}{\partial y^2}+\frac{\partial^2 v_z}{\partial z^2}\right)+\rho g_z$$

3. Energy equation in Cartesian coordinates:

$$\rho\hat{C}_P\left(\frac{\partial T}{\partial t}+v_x\frac{\partial T}{\partial x}+v_y\frac{\partial T}{\partial y}+v_z\frac{\partial T}{\partial z}\right)=k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)+\mu\Phi+\dot{q}$$

1. An incompressible Newtonian liquid film flowing down a vertical solid wall, as shown in the figure. If we consider the flow at the steady laminar flow in the fully developed region. (a) Derive an expression for the velocity profiles in the falling film? (b) What is the maximum velocity for the flow?



2. Extend Problem 1. The downflowing liquid film enters at uniform temperature T_o and the solid surface at constant temperature T_1. ($T_1 > T_o$). If we assume that in the vicinity of the wall the velocity is a linear function of y given by $v_z=\frac{\rho g \delta}{\mu}y$.

(a) Show that the energy equation reduces to $y\frac{\partial T}{\partial z} = \beta\frac{\partial^2 T}{\partial y^2}$ with the boundary conditions

B.C.1: $T = T_o$ for $z = 0$ and $y > 0$

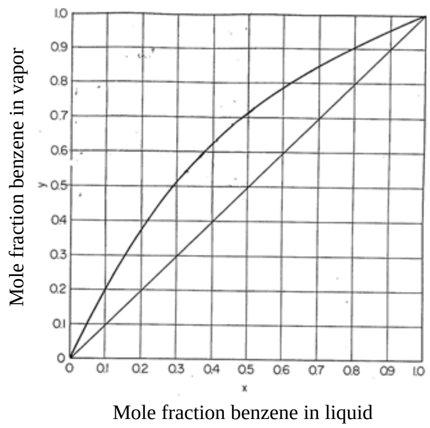
B.C.2: $T = T_o$ for $y = \infty$ and z finite

B.C.3: $T = T_1$ for $y = 0$ and $z > 0$

(b) Use the dimensionless variables $\Theta(\eta) = \frac{T - T_o}{T_1 - T_o}$ and $\eta = \frac{y}{\sqrt[3]{9\beta z}}$. Derive an expression for the temperature profiles in the falling film?

3. Asphalt pavement may achieve temperatures as high as 50^oC on a hot summer day. Assume that such a temperature exists throughout the pavement, when suddenly a rainstorm reduces the surface temperature to 20^oC. The Asphalt thermophysical properties are $\rho = 2115\frac{Kg}{m^3}$, $k = 0.062\frac{W}{m\,K}$, and $C_P = 920\frac{J}{Kg\,K}$. Calculate the total amount of energy (J/m^2) that will be transferred from the asphalt over a 30-min period in which the surface is maintained at 20^oC.(Consider that the pavement is the semi-infinite media and the equation of constant surface temperature is $\frac{T - T_s}{T_i - T_s} = \frac{2}{\sqrt{\pi}}\int_0^\eta \exp(-u^2)du$, where $\eta = \frac{x}{\sqrt{4\alpha t}}$.)

4. A mixture of 10,000 kg/hr which contains 55 wt% benzene and 45 wt% toluene is distilled under flash distillation at 101.3 kPa until 40 kg mole/hr are distilled, what is the composition of the vapor distilled and of the liquid left?



5. A single-effect evaporator is concentrating a feed solution of NaOH in water from 20 to 40 wt%. The pressure of the saturated steam used is 1 atm and the pressure in the vapor space of the evaporator is 4.745 psi. The solution entering at 150^oF and the BPR can not neglect. If the steam rate is 50 lb/hr. Calculate the economy and the capacity.

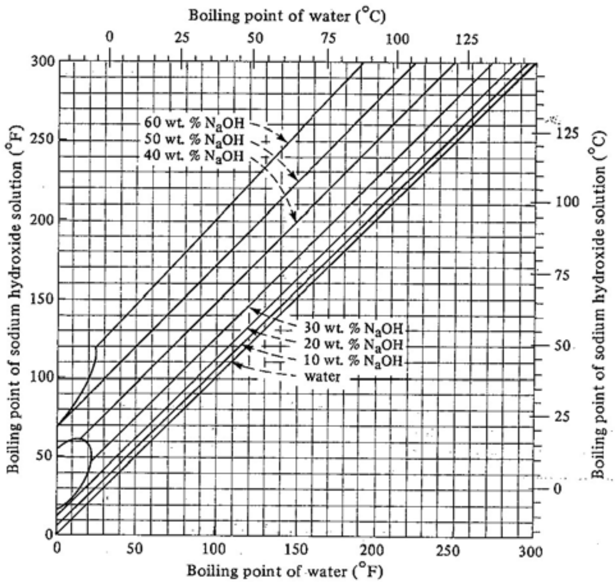
Temperature (°F)	Vapor Pressure (psia)	Specific Volume (ft^3/lb_m) Liquid	Sat'd Vapor	Enthalpy (btu/lb_m) Liquid	Sat'd Vapor	Entropy ($btu/lb_m \cdot °F$) Liquid	Sat'd Vapor
120	1.6945	0.016205	203.0	88.00	1113.5	0.16465	1.9336
130	2.225	0.016247	157.17	97.98	1117.8	0.18172	1.9109
140	2.892	0.016293	122.88	107.96	1121.9	0.19851	1.8892
150	3.722	0.016343	96.99	117.96	1126.1	0.21503	1.8684
160	4.745	0.016395	77.23	127.96	1130.1	0.23130	1.8484
170	5.996	0.016450	62.02	137.97	1134.2	0.24732	1.8293
180	7.515	0.016509	50.20	147.99	1138.2	0.26311	1.8109
190	9.343	0.016570	40.95	158.03	1142.1	0.27866	1.7932
200	11.529	0.016634	33.63	168.07	1145.9	0.29400	1.7762
210	14.125	0.016702	27.82	178.14	1149.7	0.30913	1.7599
212	14.698	0.016716	26.80	180.16	1150.5	0.31213	1.7567

■ *Properties of saturated water*

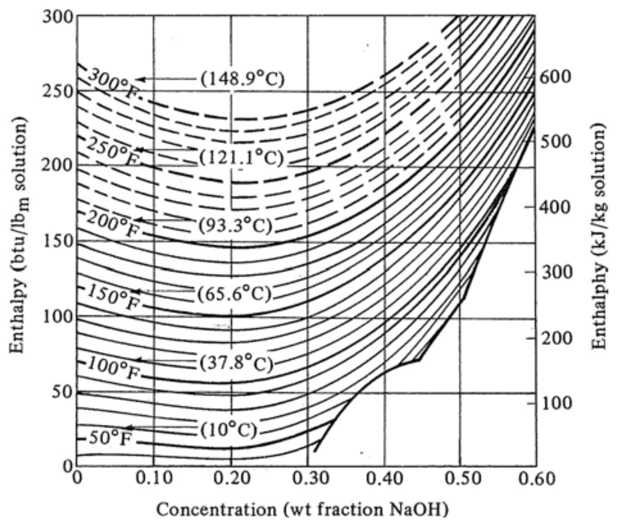
Absolute Pressure, psi (Sat. Temp., °F)		Temperature (°F) 200	300	400
	v	392.5	452.3	511.9
1.0	H	1150.1	1195.7	1241.8
(101.70)	s	2.0508	2.1150	2.1720
	v	78.15	90.24	102.24
5.0	H	1148.6	1194.8	1241.2
(162.21)	s	1.8715	1.9367	1.9941
	v	38.85	44.99	51.03
10.0	H	1146.6	1193.7	1240.5
(193.19)	s	1.7927	1.8592	1.9171
	v		30.52	34.67
14.696	H		1192.6	1239.9
(211.99)	s		1.8157	1.8741

v, specific volume, ft^3/lb ;
H, enthalpy, Btu/lb ; s, entropy, Btu/lb °F

■ *Properties of gaseous water*



■ *Dühring lines for aqueous solution of sodium hydroxide*



■ *Enthalpy – concentration chart for the system NaOH – water*