The University of Melbourne
School of Engineering

Semester 1 2011

ENGR30001 - Fluid Mechanics & Thermodynamics

Reading time ......15 mins............ Writing time ... 3 hours......

This paper has ......11.......... Pages

Authorised materials

☐ The following items are authorized (list here) ....
OR
☐ Students may have unrestricted access to all materials
OR
✓ No materials are authorised

Calculators

☐ No calculators allowed

☐ Any calculator allowed

✓ Calculators on School of Engineering approved list only allowed

Instructions to invigilators

✓ Script books to be provided

Instructions to students

All questions are to be attempted.

Full marks will be awarded for obtaining 100 marks of a potential 110 marks.

A chart, a table and a formulae page are attached at the end of the exam.

May be taken by students at the end of the exam ☐ Yes ✓ No

Paper to be held by Baillieu library ✓ Yes ☐ No

ENGR30001 Fluid Mechanics & Thermodynamics

Question 1

Perform the following using the attached steam tables as required.

i) Sketch a T-v diagram for H_20 showing the liquid, saturation and superheated regions and at least one isobar passing through each of these regions.

(2 marks)

ii) An open bucket full of hot water sits on a table. Nearby is a bucket half full of cold water. Which has the higher density? Which has the higher specific volume?

(2 marks)

Find the specific volume of water and/or steam at the following conditions using the tables provided:

iii) $p = 8$ MPa, $T = 295$ °C (dry saturated) **(1 mark)**
iv) $p = 8$ MPa, $T = 295$ °C (saturated, $x = 0.8$) **(2 marks)**
v) $p = 8$ MPa, $T = 410$ °C **(2 marks)**
vi) $p = 6$ MPa, $T = 290$ °C **(2 marks)**

Total for Question 1 = 11 marks

Question 2

i) Define gauge pressure.

(1 mark)

ii) Calculate the temperature of air at a gauge pressure of 100 kPa and density of 2000 g/m^3. $R = 287$ J/kg K for air.

(1 mark)

iii) Consider a cylinder of air capped by a leakproof, frictionless piston. The cylinder diameter is 450 mm and the initial volume is 0.08 m^3. The atmospheric pressure is 101.3kPa. The air in the cylinder is initially at 80°C and 100kPa (gauge pressure). If the temperature is raised by 30°C but the pressure remains constant, what is the work (in kJ) done on the atmosphere?

(4 marks)

iv) Consider a cylinder of liquid capped by a leakproof, frictionless piston. By cooling the cylinder, the liquid freezes. If the heat transferred from the system is 10 kJ/kg and the specific work done by the piston is 1 kJ/kg, what is the change in specific internal energy of the liquid?

(1 mark)

v) Define specific heat in words and as an equation.

(2 marks)

vi) For what kind of process or processes does the following equation hold:

$$pv^{\gamma} = \text{const}$$

(1 marks)

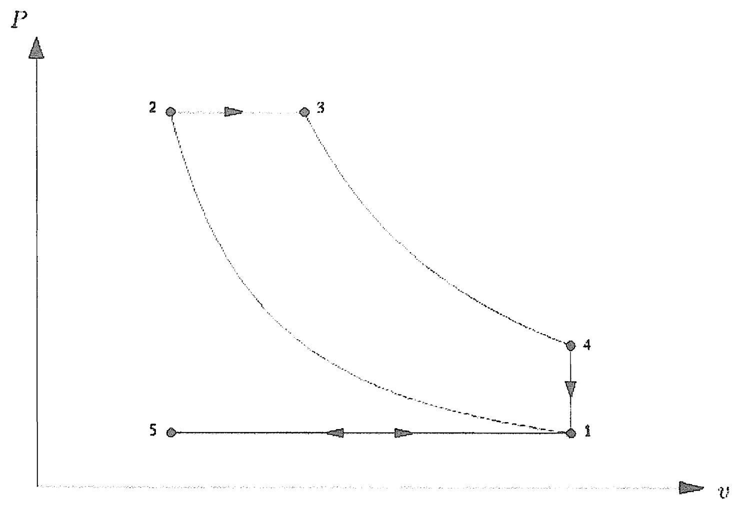
vii) State Boyle's Law AND Charles' Law.

(2 marks)

Total for Question 2 = 12 marks

Question 3

The figure below shows an air-standard cycle ($P - v$ diagram)



i) Which of the cycles does this represent (Otto, Diesel, Joule/Brayton, Rankine)?

(1 mark)

ii) List the processes in the cycle, describing the type of process (e.g., for the Otto or Diesel cycle, process 1 – 2 is an adiabatic compression process during which the piston is moving up and compressing the gas).

(3 marks)

iii) Prove the equation for the thermal efficiency for the above cycle is

$$\eta = \frac{W_{out}}{Q_{in}} = 1 - \frac{1}{r_v^{\gamma-1}}\left[\frac{r_c^{\gamma}-1}{\gamma(r_c-1)}\right]$$

Given

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1}, \quad \frac{T_3}{T_2} = \left(\frac{v_3}{v_2}\right) \quad \text{and} \quad \frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{\gamma-1}$$

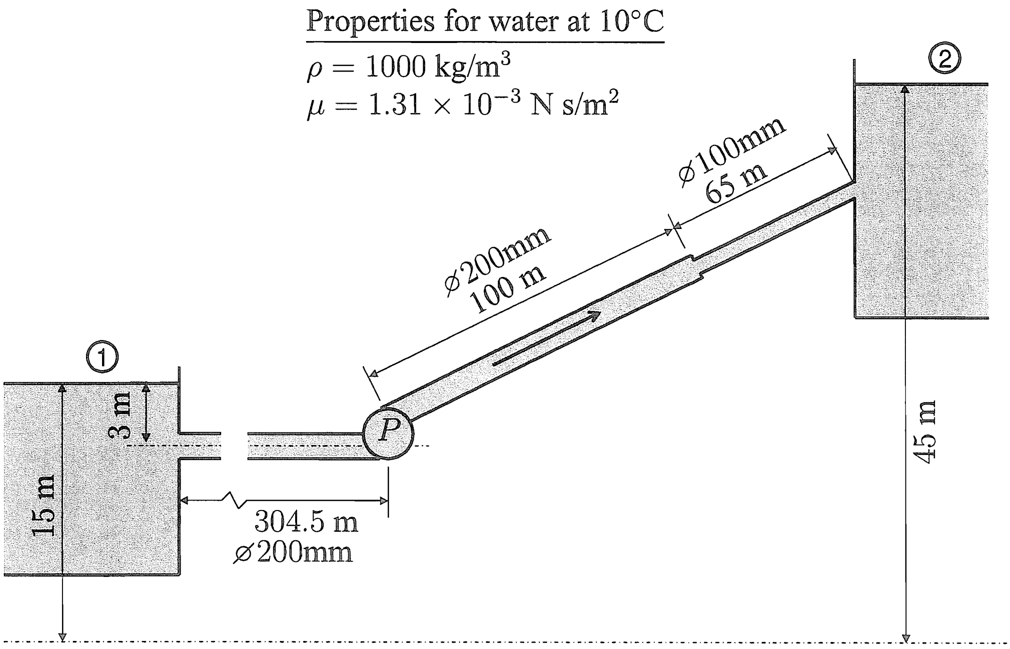
and define r_v, r_c and γ. **(5 marks)**

iv) If a compression ratio of 20:1 and cut-off ratio of 1.8:1 was employed, determine the efficiency of an engine using the above cycle. $\gamma = 1.4$, $R = 0.287$ kJ/kg K. **(1 mark)**

v) Is this efficiency higher or lower than that of a Carnot cycle operating between the same maximum and minimum temperatures as this engine (state Carnot efficiency)? **(2 marks)**

Total for Question 3 = 12 marks

Question 4



The pipeline and pump system shown above is used to deliver water at 10°C from reservoir 1 to reservoir 2 at a volume flow rate of 70 litres/s. The first pipe on the suction side of the pump is 304.5 m long with diameter 200 mm. After the pump the pipe continues for 100 m with diameter 200 mm, followed by a sudden contraction into a 65 m long pipe of diameter 100 mm. All piping has a roughness height of 0.0002 m. Assume the reservoirs are large and open to atmosphere.

(*a*) Determine the Reynolds number and friction factor for both pipe diameters. **(6 marks)**

(*b*) Determine the total head losses in the system (due to frictional and minor losses). **(7 marks)**

minor loss	loss coefficient
inlet loss	0.5
exit loss	1
sudden contraction	$\frac{1}{2}\left(1 - \left(\frac{d_{small}}{d_{large}}\right)^2\right)$

(*c*) How much power must be supplied by the pump. **(5 marks)**

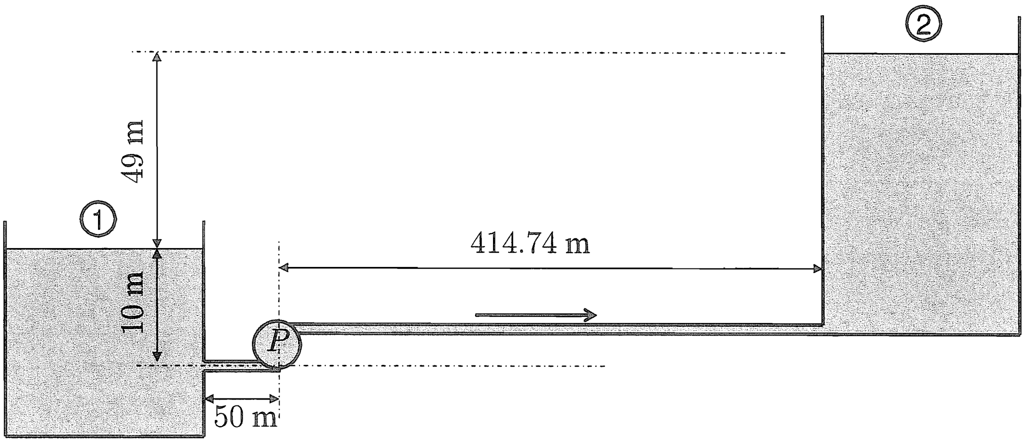
(*d*) Where does the lowest head in the system occur? **(1 mark)**

Total for question 4 = 19 marks

Question 5

Properties for water at 20°C

$\rho = 1000$ kg/m^3
$\mu = 1 \times 10^{-3}$ N s/m^2
$p_{vp} = 2333$ Pa



A pump is used to deliver water at 20°C between two large reservoirs (from reservoir 1 to reservoir 2) through 464.74 m of pipe with internal diameter 0.4m. The free surface of reservoir 2 is located 49 m above the free surface of reservoir 1. For volume flow rates of greater than 0.5m^3/s, the Fanning friction factor is found to have a constant value 0.008. Both reservoirs are open to atmosphere.

(a) Using the details given, write out an expression for the system head purely as a function of Q (for the constant f case where $Q > 0.5\text{m}^3/\text{s}$). Ignore all minor losses. **(6 marks)**

(b) You are provided the following equation from the manufacturer for the pump head as a function of volume flow rate,

$$h_p = 149 - 20Q^2$$

Determine algebraically the volume flow rate at the operating point of the system. **(3 marks)**

(c) The required Net Positive Suction Head ($NPSH_R$) supplied by the pump manufacturer is 8 m. Determine whether the pump is within the permissable operating range at the operating point. The vapour pressure of water at 20°C is 2333 Pa. Assume that atmospheric pressure is 101325 Pa. **(5 marks)**

(d) Estimate the roughness height for the pipe. **(2 marks)**

Total for question 5 = 16 marks

Question 6

The mechanical energy equation for horizontal, isothermal, ideal, compressible gas flow in a pipe of uniform cross-section is

$$\frac{P_2^2 - P_1^2}{2(RT/M)} + \left(\frac{G}{A}\right)^2 \ln\left(\frac{P_1}{P_2}\right) + \frac{2\,fL}{D}\left(\frac{G}{A}\right)^2 = 0$$

where all symbols have their usual meaning.

a) What is meant by the term "choked flow"? **(2 marks)**

b) Explain the significance of the pressure P_w in the following relation:

$$\frac{4\,fL}{D} = \left(\frac{P_1}{P_w}\right)^2 - \ln\left(\frac{P_1}{P_w}\right)^2 - 1$$

(2 marks)

Nitrogen gas flows isothermally at 150 °C through such a pipe having internal diameter 55 mm and length 10m. The gas pressure at the pipe entrance is 600 kPa and the pressure at the pipe exit is 400 kPa. The Fanning friction factor $f = 0.005$

c) Show that the flow through the pipe is not choked **(5 marks)**
d) Calculate the mass flow rate of nitrogen through the pipe **(8 marks)**
e) Calculate the gas velocity at the pipe exit as a percentage of the sonic velocity **(5 marks)**

Gram molecular weight of nitrogen	28
Gas constant R	8.314 J mol^{-1} K^{-1}

Total for Question 6 = 22 marks

Question 7

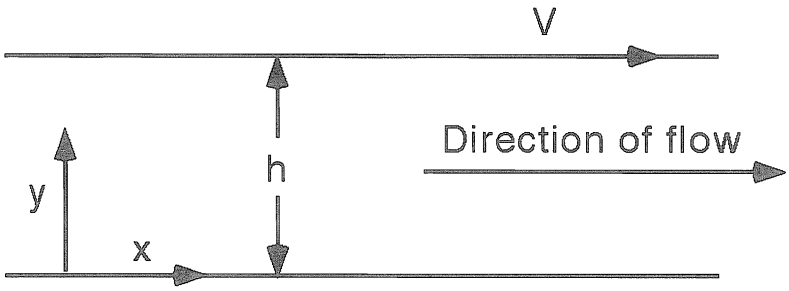
The liquid in a production stirred tank system in which vortexing occurs has viscosity equal to 0.005 Pa s and density equal to 900 kg m^{-3}. A 1/5th scale laboratory model of the production unit is built to investigate the mixing performance. The liquid used in the laboratory model is chosen to ensure dynamic similarity on both Reynolds number and Froude number.

Calculate the kinematic viscosity required for the laboratory liquid. Give units for your numerical answer. **(6 marks)**

Total for Question 7 = 6 marks

Question 8

An incompressible viscous Newtonian fluid is located in the space between two infinitely long parallel plates that are a distance h apart. Let x and y be the coordinates parallel and normal to the plates, respectively. The coordinate z is perpendicular to the x-y plane. The lower plate is stationary but the upper plate is moving with velocity V, thereby imparting motion to the fluid. The fluid is also being driven by an applied pressure gradient in the x-direction. The flow is steady, parallel to the plates, and planar in the x-y plane with no dependence on the coordinate z



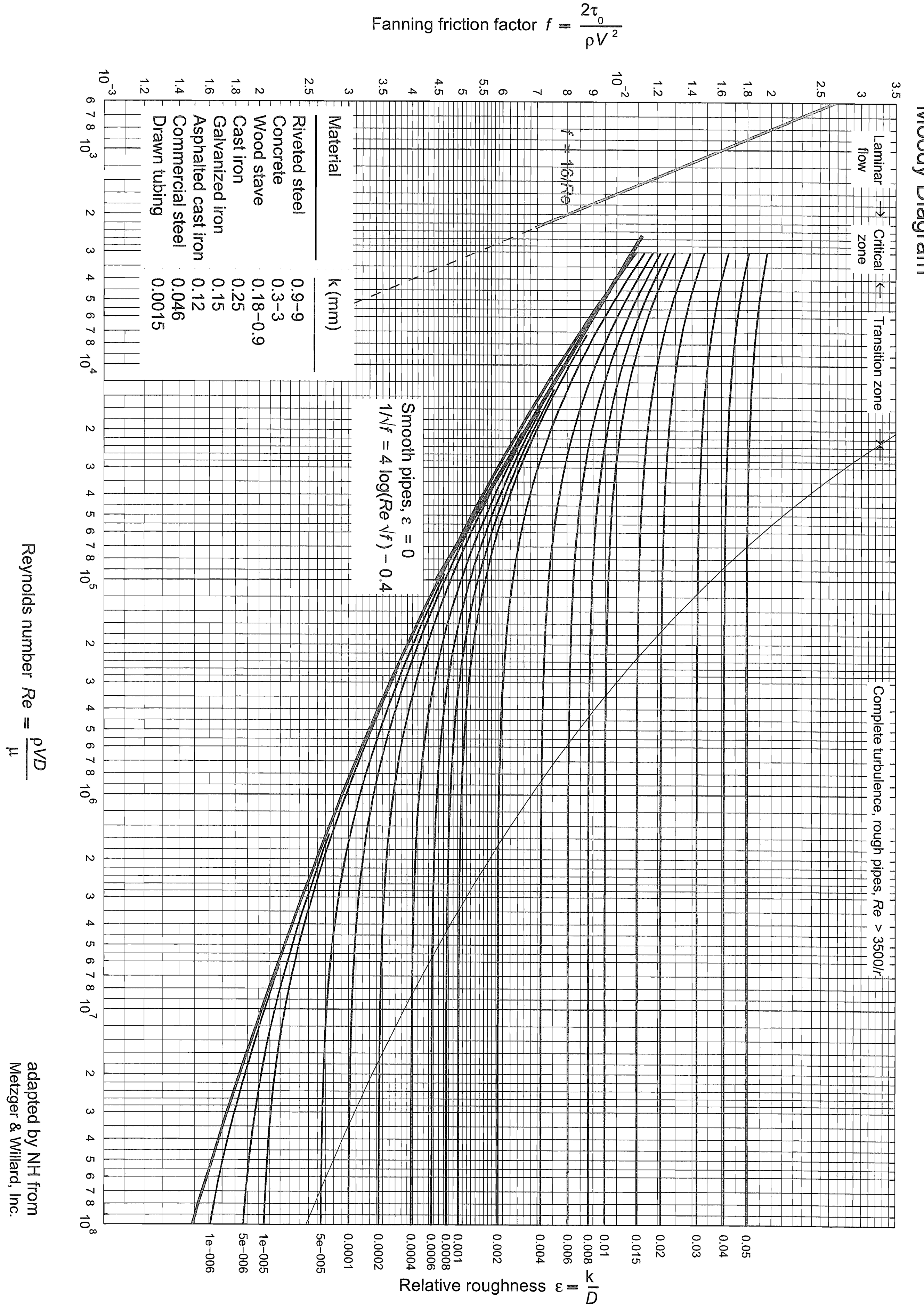
a) Show that the velocity v_x is a function of y only **(2 marks)**

b) Show that the pressure gradient $\dfrac{\partial p}{\partial x}$ must be constant **(5 marks)**

c) Find an expression for the velocity (v_x) profile assuming the pressure falls from a pressure P_1 to a pressure P_2 over a length L along the channel **(5 marks)**

Total for Question 8 = 12 marks

Total for the paper = 110 marks



Fanning friction factor $f = \frac{2\tau_0}{\rho V^2}$
Moody Diagram
Laminar flow
Critical zone
Transition zone
Complete turbulence, rough pipes, Re > 3500/r
f = 16/Re
Smooth pipes, ε = 0
$1/\sqrt{f} = 4 \log(Re\sqrt{f}) - 0.4$
Material | k (mm)
Riveted steel | 0.9–9
Concrete | 0.3–3
Wood stave | 0.18–0.9
Cast iron | 0.25
Galvanized iron | 0.15
Asphalted cast iron | 0.12
Commercial steel | 0.046
Drawn tubing | 0.0015
Reynolds number $Re = \frac{\rho V D}{\mu}$
Relative roughness $\varepsilon = \frac{k}{D}$
adapted by NH from Metzger & Willard, Inc.

Continuity and Navier-Stokes equations for incompressible homogeneous fluids in Cartesian, cylindrical, and spherical coordinates

Cartesian	Cylindrical	Spherical
	Continuity equation	
$\frac{\partial v_x}{\partial x}+\frac{\partial v_y}{\partial y}+\frac{\partial v_z}{\partial z}=0$	$\frac{1}{r}\frac{\partial (rv_r)}{\partial r}+\frac{1}{r}\left(\frac{\partial v_\theta}{\partial \theta}\right)+\frac{\partial v_z}{\partial z}=0$	$\frac{1}{r^2}\frac{\partial (r^2 v_r)}{\partial r}+\frac{1}{r\sin\theta}\frac{\partial (v_\theta \sin\theta)}{\partial \theta}+\frac{1}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi}=0$
	Navier-Stokes equation	
$\rho\left(\frac{\partial v_x}{\partial t}+v_x\frac{\partial v_x}{\partial x}+v_y\frac{\partial v_x}{\partial y}+v_z\frac{\partial v_x}{\partial z}\right) =-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 v_x}{\partial x^2}+\frac{\partial^2 v_x}{\partial y^2}+\frac{\partial^2 v_x}{\partial z^2}\right)$	$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}-\frac{v_\theta^2}{r}+v_z\frac{\partial v_r}{\partial z}\right) =-\frac{\partial p}{\partial r}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_r)\right)+\frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2}-\frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}+\frac{\partial^2 v_r}{\partial z^2}\right]$	$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_r}{\partial \phi}-\frac{v_\theta^2+v_\phi^2}{r}\right) =-\frac{\partial p}{\partial r}+\mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial v_r}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial v_r}{\partial \theta}\right) +\frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_r}{\partial \phi^2}-\frac{2v_r}{r^2}-\frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta}-\frac{2v_\theta\cot\theta}{r^2}-\frac{2}{r^2\sin\theta}\frac{\partial v_\phi}{\partial \phi}\right]$
$\rho\left(\frac{\partial v_y}{\partial t}+v_x\frac{\partial v_y}{\partial x}+v_y\frac{\partial v_y}{\partial y}+v_z\frac{\partial v_y}{\partial z}\right) =-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v_y}{\partial x^2}+\frac{\partial^2 v_y}{\partial y^2}+\frac{\partial^2 v_y}{\partial z^2}\right)$	$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_r v_\theta}{r}+v_z\frac{\partial v_\theta}{\partial z}\right) =-\frac{1}{r}\frac{\partial p}{\partial \theta}+\mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_\theta)\right)+\frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2}+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}+\frac{\partial^2 v_\theta}{\partial z^2}\right]$	$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_\theta}{\partial \phi}+\frac{v_r v_\theta}{r}-\frac{v_\phi^2\cot\theta}{r}\right) =-\frac{1}{r}\frac{\partial p}{\partial \theta}+\mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial v_\theta}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial v_\theta}{\partial \theta}\right) +\frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_\theta}{\partial \phi^2}+\frac{2}{r^2}\frac{\partial v_r}{\partial \theta}-\frac{v_\theta}{r^2\sin^2\theta}-\frac{2\cos\theta}{r^2\sin^2\theta}\frac{\partial v_\phi}{\partial \phi}\right]$
$\rho\left(\frac{\partial v_z}{\partial t}+v_x\frac{\partial v_z}{\partial x}+v_y\frac{\partial v_z}{\partial y}+v_z\frac{\partial v_z}{\partial z}\right) =-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 v_z}{\partial x^2}+\frac{\partial^2 v_z}{\partial y^2}+\frac{\partial^2 v_z}{\partial z^2}\right)$	$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right) =-\frac{\partial p}{\partial z}+\mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right)+\frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2}+\frac{\partial^2 v_z}{\partial z^2}\right]$	$\rho\left(\frac{\partial v_\phi}{\partial t}+v_r\frac{\partial v_\phi}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\phi}{\partial \theta}+\frac{v_\phi}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi}+\frac{v_r v_\phi}{r}+\frac{v_\theta v_\phi\cot\theta}{r}\right) =-\frac{1}{r\sin\theta}\frac{\partial p}{\partial \phi}+\mu\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial v_\phi}{\partial r}\right)+\frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial v_\phi}{\partial \theta}\right) +\frac{1}{r^2\sin^2\theta}\frac{\partial^2 v_\phi}{\partial \phi^2}-\frac{v_\phi}{r^2\sin^2\theta}+\frac{2}{r^2\sin\theta}\frac{\partial v_r}{\partial \phi}+\frac{2\cos\theta}{r^2\sin^2\theta}\frac{\partial v_\theta}{\partial \phi}\right]$

MN/m²

°C T \ p	0.001	0.01	0.02	0.05	0.1	0.5	1	2	4	6	8	10	15	20	25	30	35	40	45	50	60	80	100	T
0	999.8	999.8	999.8	999.8	999.8	1000	1000	1001	1002	1003	1004	1005	1007	1010	1012	1014	1017	1019	1022	1024	1028	1037	1046	0
5	999.9	999.8	999.8	999.8	999.8	1000	1000	1001	1002	1003	1004	1005	1007	1009	1012	1014	1016	1019	1021	1023	1028	1036	1044	5
10	0.00766	999.8	999.8	999.8	999.8	1000	1000	1001	1002	1003	1004	1004	1007	1009	1011	1014	1016	1018	1020	1022	1027	1035	1043	10
20	0.00739	998.3	998.3	998.3	998.3	998.5	998.7	999.2	1000	1001	1002	1003	1005	1007	1009	1012	1014	1016	1018	1020	1024	1032	1040	20
25	0.00727	997.0	997.0	997.0	997.0	997.2	997.4	997.9	998.8	999.7	1001	1001	1004	1006	1008	1010	1012	1014	1016	1018	1022	1030	1038	25
30	0.00715	995.7	995.7	995.7	995.8	995.9	996.2	996.6	997.5	998.4	999.2	1000	1002	1004	1007	1009	1011	1013	1015	1017	1021	1029	1036	30
40	0.00692	992.3	992.3	992.3	992.3	992.5	992.7	993.1	994.0	994.9	995.7	996.6	998.7	1001	1003	1005	1007	1009	1011	1013	1017	1025	1032	40
50	0.00671	0.0673	988.0	988.0	988.1	988.2	988.5	988.9	989.8	990.6	991.5	992.4	994.5	996.6	998.7	1001	1003	1005	1007	1009	1013	1020	1027	50
60	0.00651	0.0652	981.9	983.2	983.2	983.4	983.6	984.0	984.9	985.8	986.6	987.5	989.6	991.8	993.8	995.9	997.9	999.9	1002	1004	1008	1015	1023	60
70	0.00632	0.0633	0.1269	977.7	977.7	977.9	978.1	978.5	979.4	980.3	981.2	982.1	984.2	986.4	988.5	990.6	992.6	994.7	996.7	998.6	1003	1010	1017	70
80	0.00614	0.0615	0.1232	971.6	971.7	971.8	972.1	972.5	973.4	974.3	975.2	976.1	978.3	980.5	982.7	984.8	986.9	988.9	990.9	993.0	996.9	1005	1012	80
90	0.00597	0.0598	0.1197	0.301	965.1	965.3	965.5	966.0	966.9	967.9	968.8	969.7	972.0	974.2	976.4	978.5	980.7	982.8	984.8	986.9	990.9	998.7	1006	90
100	0.00581	0.0582	0.1165	0.293	0.590	958.3	958.6	959.0	960.0	960.9	961.9	962.8	965.1	967.4	969.7	971.9	974.1	976.2	978.3	980.4	984.5	992.5	1000	100
125	0.00544	0.0545	0.1091	0.274	0.550	938.8	939.1	939.6	940.6	941.7	942.7	943.7	946.2	948.7	951.1	953.5	955.9	958.2	960.4	962.7	967.0	975.5	983.5	125
150	0.00512	0.0512	0.1026	0.257	0.516	916.8	917.1	917.7	918.8	920.0	921.1	922.2	925.0	927.7	930.4	933.0	935.6	938.1	940.5	943.0	947.7	956.7	965.3	150
175	0.00484	0.0484	0.0968	0.243	0.487	2.504	892.1	892.8	894.1	895.4	896.7	898.0	901.1	904.2	907.2	910.1	912.9	915.7	918.4	921.1	926.3	936.2	945.5	175
200	0.00458	0.0458	0.0917	0.230	0.460	2.353	4.856	865.0	866.6	868.1	869.6	871.1	874.7	878.2	881.6	884.9	888.1	891.3	894.3	897.3	903.1	914.0	924.1	200
225	0.00435	0.0435	0.0871	0.218	0.437	2.223	4.554	9.643	835.1	837.0	838.8	840.6	844.9	849.0	853.0	856.9	860.6	864.3	867.8	871.2	877.7	889.9	901.1	225
250	0.00414	0.0414	0.0829	0.207	0.416	2.108	4.296	8.973	799.2	801.5	803.8	806.1	811.4	816.5	821.3	826.0	830.4	834.7	838.8	842.7	850.3	864.1	876.6	250
275	0.00395	0.0395	0.0791	0.198	0.396	2.006	4.073	8.429	18.34	759.3	762.2	765.2	772.3	778.9	785.1	790.9	796.4	801.6	806.6	811.3	820.2	836.2	850.4	275
300	0.00378	0.0378	0.0756	0.189	0.379	1.914	3.876	7.968	17.00	27.67	41.21	715.4	725.7	735.0	743.3	751.0	758.1	764.7	770.9	776.7	787.5	806.4	822.7	300
325	0.00362	0.0362	0.0725	0.181	0.363	1.830	3.700	7.569	15.94	25.42	36.54	50.40	663.6	679.0	691.8	703.0	712.9	721.8	729.9	737.5	751.0	773.9	792.9	325
350	0.00348	0.0348	0.0696	0.174	0.348	1.754	3.541	7.217	15.05	23.68	33.39	44.60	87.24	600.1	625.0	643.5	658.6	671.4	682.6	692.6	710.0	738.1	760.6	350
375	0.00334	0.0334	0.0669	0.167	0.335	1.685	3.396	6.902	14.29	22.29	31.04	40.76	72.04	132.0	488.7	555.4	586.5	608.5	625.9	640.4	664.2	699.7	726.5	375
400	0.00322	0.0322	0.0644	0.161	0.322	1.620	3.263	6.617	13.63	21.11	29.15	37.87	63.85	100.5	166.3	353.3	473.8	523.8	555.1	578.3	612.6	658.8	691.4	400
425	0.00310	0.0310	0.0621	0.155	0.311	1.561	3.141	6.357	13.04	20.09	27.57	35.55	58.37	87.21	127.0	189.3	292.3	390.6	455.0	497.2	551.1	613.6	653.9	425
450	0.00300	0.0300	0.0599	0.150	0.300	1.506	3.028	6.119	12.51	19.19	26.22	33.62	54.20	78.70	109.0	148.5	201.8	272.1	343.2	401.3	479.9	564.3	613.9	450
475	0.00290	0.0290	0.0579	0.145	0.290	1.455	2.923	5.900	12.02	18.39	25.03	31.97	50.87	72.54	97.92	128.3	165.4	210.5	262.9	315.9	403.9	510.8	571.2	475
500	0.00280	0.0280	0.0561	0.140	0.280	1.407	2.825	5.696	11.58	17.67	23.98	30.53	48.09	67.70	89.86	115.2	144.4	178.1	216.2	257.6	338.8	457.0	528.2	500
550	0.00263	0.0263	0.0527	0.132	0.263	1.320	2.649	5.331	10.80	16.41	22.17	28.09	43.65	60.43	78.61	98.37	119.9	143.2	168.5	195.6	253.3	361.8	445.3	550
600	0.00248	0.0248	0.0496	0.124	0.248	1.244	2.494	5.012	10.13	15.34	20.66	26.10	40.19	55.06	70.79	87.44	105.0	123.6	143.2	163.6	206.8	295.9	374.8	600
650	0.00235	0.0235	0.0469	0.117	0.235	1.176	2.356	4.731	9.537	14.42	19.38	24.41	37.36	50.83	64.87	79.48	94.68	110.5	126.8	143.7	178.7	251.6	322.0	650
700	0.00223	0.0223	0.0445	0.111	0.223	1.115	2.233	4.481	9.017	13.61	18.26	22.96	34.98	47.37	60.13	73.28	86.80	100.7	115.0	129.5	159.5	221.3	282.8	700
750	0.00212	0.0212	0.0424	0.106	0.212	1.060	2.123	4.256	8.555	12.89	17.28	21.70	32.94	44.45	56.21	68.24	80.52	93.04	105.8	118.8	145.2	199.3	253.0	750
800	0.00202	0.0202	0.0404	0.101	0.202	1.011	2.023	4.054	8.140	12.26	16.41	20.58	31.17	41.94	52.89	64.03	75.33	86.80	98.42	110.2	134.0	182.5	230.4	800
T_{sat}	6.98	45.83	60.09	81.35	99.63	151.8	179.9	212.4	250.3	275.5	295.0	311.0	342.1	365.7										
ρ_f	999.9	989.9	983.1	970.8	958.4	915.0	887.0	849.9	798.7	758.3	722.4	688.4	603.2	490.9										
ρ_g	0.00774	0.0681	0.1307	0.309	0.590	2.669	5.147	10.05	20.10	30.83	42.51	55.43	96.71	170.2										

Density of Water & Steam kg/m³

Table 6, Density