UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAM
SEMESTER II
2014/2015 SESSION

LIST OF USEFUL FORMULAS AND FLUID PROPERTIES

SUBJECT NAME : FLUID MECHANICS

SUBJECT CODE : BBM 30103

THIS APPENDIX NEEDS TO BE RETURNED AFTER THE EXAMINATION.

THIS APPENDIX CONTAINS **NINE(9)** PRINTED PAGES
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LIST OF FORMULA

List of Useful Formulas & Fluid Properties

Newton's Law of Viscosity, $\tau = \mu \frac{du}{dy}$ — τ=shear stress; μ=viscosity
Specific Weight, $\omega = \rho g$ — K = °C+273
Specific Gravity, S.G. = $\frac{\rho}{\rho_{H_2O@4°C}}$ — °R = °F+460
Ideal Gas Law, $p = \rho RT$
where
p=pressure
ρ = density
T = Temperature in Kelvin
$R = 287 Jkg^{-1}K^{-1} = 4110 Jkg^{-1}K^{-1}$

Pressure Equation

$p = p_o + \rho g h = p_o + \rho h$

Gravity, $g = 9.81 m/s^2 = 32.2 ft/s^2$
$P_{atm} = 101.33 kPa(abs) = 2116.2 lb/ft^2(abs) = 14.7 psi(abs)$
$\rho_{air} = 1.225 kg/m^3$
$\gamma_{air} = 12.014 N/m^3 = 7.647 \times 10^{-2} lb/ft^3$

Common Liquid Properties

Mercury, $\gamma_{Hg} = 847 lb/ft^3 = 133 kN/m^3$
Water, $\gamma_{H_2O} = 62.4 lb/ft^3 = 9.81 kN/m^3$, $\rho_{H_2O} = 1000 kg/m^3$
Glycerin, $\gamma_{glycerin} = 78.4 lb/ft^3$

Hydrostatic Pressure on a Plane Surface

Resultant Force, $F_R = \gamma h_c A$, h_c = centroid distance from surface A = area, $()_c$ = centroid

Position of Resultant Force

$y_R = \frac{I_{xc}}{y_c A} + y_c$

$x_R = \frac{I_{xyc}}{y_c A} + x_c$

Bernoulli Equation

$$P_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = P_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2$$

or $\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$

Conservation of mass, $\rho_1 A_1 V_1 = \rho_2 A_2 V_2$ or $A_1 V_1 = A_2 V_2$ given $\rho_1 = \rho_2$

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Viscous Flow in Pipes

Reynolds Number, $Re = \frac{\rho V D}{\mu} = \frac{VD}{\upsilon}$ where kinematic viscosity, $\upsilon = \frac{\mu}{\rho}$

Entrance Length $\frac{l_e}{D} = 0.06Re$ (Laminar Flow)

$\frac{l_e}{D} = 4.4(Re)^{1/6}$ (Turbulent Flow)

Fully Developed Laminar Pipe Flow

Pressure Drop, $\Delta p = \frac{4l\tau_w}{D}$ $\tau_w =$ wall sheer stress

Volume Flowrate, $Q = \frac{\pi D^4 \Delta p}{128\mu l}$ $l =$ length

Friction Factor, $f = \frac{64}{Re} = \frac{8\tau_w}{\rho V^2}$

Pressure drop for a horizontal pipe, $\Delta p = f\frac{l}{D}\frac{\rho V^2}{2}$

Pipe Losses

Major Losses, $h_{\text{L Major}} = f\frac{l}{D}\frac{V^2}{2g}$

Colebrook Formula, $\frac{1}{\sqrt{f}} = \text{-}2.0\ \log(\frac{\epsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}})$

Explicit alternative to Colebrook Formula, $\frac{1}{\sqrt{f}} = \text{-}1.8\ \log[(\frac{\epsilon/D}{3.7})^{1.11} + \frac{6.9}{Re}]$

Minor Losses, $h_{\text{L Minor}} = K_L\frac{V^2}{2g}$

$\epsilon =$ Pipe Equivalent Roughness

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Conversion Tables

	To Convert from	to	Multiply by
Acceleration	ft/s^2	m/s^2	3.048 E − 1
Area	ft^2	m^2	9.290 E − 2
Density	lbm/ft^3	kg/m^3	1.602 E + 1
	$slugs/ft^3$	kg/m^3	5.154 E + 2
Energy	Btu	J	1.055 E + 3
	ft · lb	J	1.356
Force	lb	N	4.448
Length	ft	m	3.048 E − 1
	in.	m	2.540 E − 2
	mile	m	1.609 E + 3
Mass	lbm	kg	4.536 E − 1
	slug	kg	1.459 E + 1
Power	ft · lb/s	W	1.356
	hp	W	7.457 E + 2
Pressure	in. Hg (60 °F)	N/m^2	3.377 E + 3
	lb/ft^2 (psf)	N/m^2	4.788 E + 1
	$lb/in.^2$ (psi)	N/m^2	6.895 E + 3
Specific weight	lb/ft^3	N/m^3	1.571 E + 2
Temperature	°F	°C	$T_C = (5/9)(T_F - 32°)$
	°R	K	5.556 E − 1
Velocity	ft/s	m/s	3.048 E − 1
	mi/hr (mph)	m/s	4.470 E − 1
Viscosity (dynamic)	$lb \cdot s/ft^2$	$N \cdot s/m^2$	4.788 E + 1
Viscosity (kinematic)	ft^2/s	m^2/s	9.290 E − 2
Volume flowrate	ft^3/s	m^3/s	2.832 E − 2
	gal/min (gpm)	m^3/s	6.309 E − 5

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Conversion Tables

	To Convert from	to	Multiply by
Acceleration	m/s^2	ft/s^2	3.281
Area	m^2	ft^2	1.076 E + 1
Density	kg/m^3	lbm/ft^3	6.243 E − 2
	kg/m^3	$slugs/ft^3$	1.940 E − 3
Energy	J	Btu	9.478 E − 4
	J	ft · lb	7.376 E − 1
Force	N	lb	2.248 E − 1
Length	m	ft	3.281
	m	in.	3.937 E + 1
	m	mile	6.214 E − 4
Mass	kg	lbm	2.205
	kg	slug	6.852 E − 2
Power	W	ft · lb/s	7.376 E − 1
	W	hp	1.341 E − 3
Pressure	N/m^2	in. Hg (60 °F)	2.961 E − 4
	N/m^2	lb/ft^2 (psf)	2.089 E − 2
	N/m^2	$lb/in.^2$ (psi)	1.450 E − 4
Specific weight	N/m^3	lb/ft^3	6.366 E − 3
Temperature	°C	°F	$T_F = 1.8\,T_C + 32°$
	K	°R	1.800
Velocity	m/s	ft/s	3.281
	m/s	mi/hr (mph)	2.237
Viscosity (dynamic)	$N \cdot s/m^2$	$lb \cdot s/ft^2$	2.089 E − 2
Viscosity (kinematic)	m^2/s	ft^2/s	1.076 E + 1
Volume flowrate	m^3/s	ft^3/s	3.531 E + 1
	m^3/s	gal/min (gpm)	1.585 E + 4

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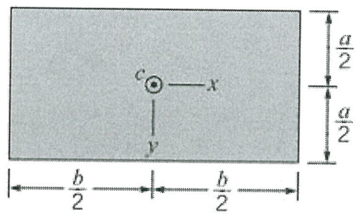
Geometric Properties of Common Shapes



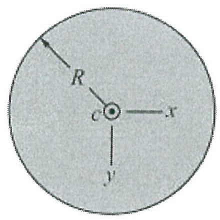
(a) Rectangle

$A = ba$

$I_{xc} = \frac{1}{12} ba^3$

$I_{yc} = \frac{1}{12} ab^3$

$I_{xyc} = 0$

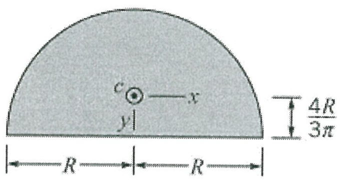


(b) Circle

$A = \pi R^2$

$I_{xc} = I_{yc} = \frac{\pi R^4}{4}$

$I_{xyc} = 0$



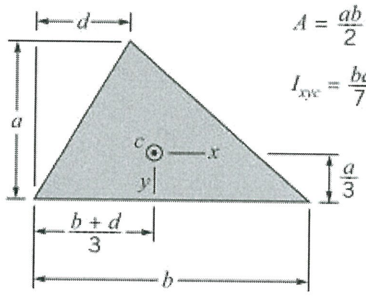
(c) Semicircle

$A = \frac{\pi R^2}{2}$

$I_{xc} = 0.1098R^4$

$I_{yc} = 0.3927R^4$

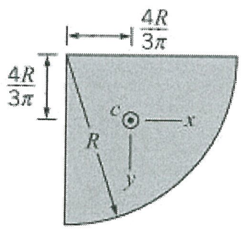
$I_{xyc} = 0$



(d) Triangle

$A = \frac{ab}{2}$ $\quad I_{xc} = \frac{ba^3}{36}$

$I_{xyc} = \frac{ba^2}{72}(b - 2d)$



(e) Quarter circle

$A = \frac{\pi R^2}{4}$

$I_{xc} = I_{yc} = 0.05488R^4$

$I_{xyc} = -0.01647R^4$

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Dimension Associated with Common Physical Quantities

	FLT System	MLT System
Acceleration	LT^{-2}	LT^{-2}
Angle	$F^0L^0T^0$	$M^0L^0T^0$
Angular acceleration	T^{-2}	T^{-2}
Angular velocity	T^{-1}	T^{-1}
Area	L^2	L^2
Density	$FL^{-4}T^2$	ML^{-3}
Energy	FL	ML^2T^{-2}
Force	F	MLT^{-2}
Frequency	T^{-1}	T^{-1}
Heat	FL	ML^2T^{-2}
Length	L	L
Mass	$FL^{-1}T^2$	M
Modulus of elasticity	FL^{-2}	$ML^{-1}T^{-2}$
Moment of a force	FL	ML^2T^{-2}
Moment of inertia (area)	L^4	L^4
Moment of inertia (mass)	FLT^2	ML^2
Momentum	FT	MLT^{-1}

	FLT System	MLT System
Power	FLT^{-1}	ML^2T^{-3}
Pressure	FL^{-2}	$ML^{-1}T^{-2}$
Specific heat	$L^2T^{-2}\Theta^{-1}$	$L^2T^{-2}\Theta^{-1}$
Specific weight	FL^{-3}	$ML^{-2}T^{-2}$
Strain	$F^0L^0T^0$	$M^0L^0T^0$
Stress	FL^{-2}	$ML^{-1}T^{-2}$
Surface tension	FL^{-1}	MT^{-2}
Temperature	Θ	Θ
Time	T	T
Torque	FL	ML^2T^{-2}
Velocity	LT^{-1}	LT^{-1}
Viscosity (dynamic)	$FL^{-2}T$	$ML^{-1}T^{-1}$
Viscosity (kinematic)	L^2T^{-1}	L^2T^{-1}
Volume	L^3	L^3
Work	FL	ML^2T^{-2}

Equivalent Roughness for New Pipes

	Equivalent Roughness, ε	
Pipe	**Feet**	**Millimeters**
Riveted steel	0.003–0.03	0.9–9.0
Concrete	0.001–0.01	0.3–3.0
Wood stave	0.0006–0.003	0.18–0.9
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Commercial steel or wrought iron	0.00015	0.045
Drawn tubing	0.000005	0.0015
Plastic, glass	0.0 (smooth)	0.0 (smooth)

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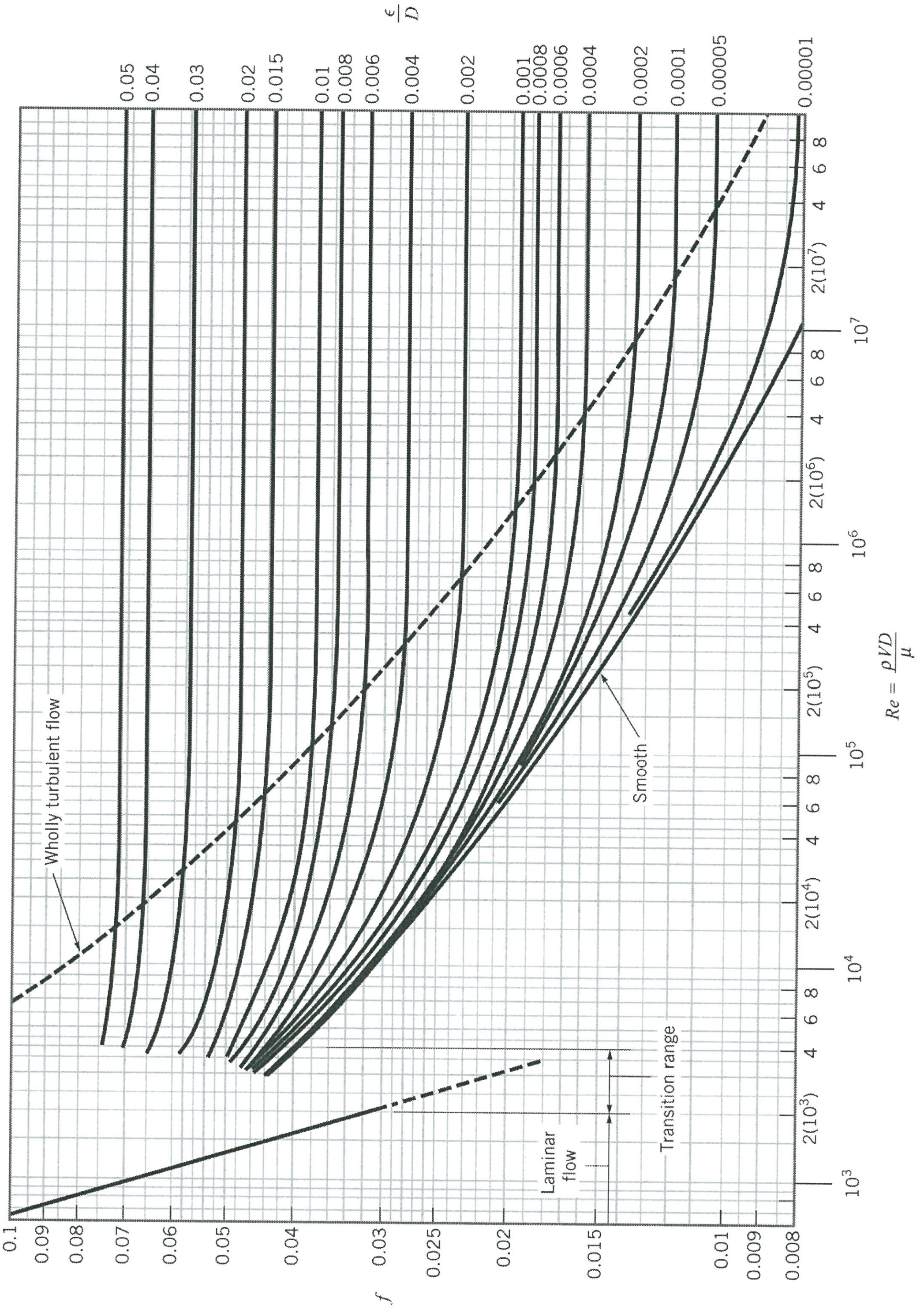
Moody Chart - Friction factor as a function of Reynolds Number and relative roughness for round pipes



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Loss Coefficient for Pipe Components

Component	K_L
a. Elbows	
Regular 90°, flanged	0.3
Regular 90°, threaded	1.5
Long radius 90°, flanged	0.2
Long radius 90°, threaded	0.7
Long radius 45°, flanged	0.2
Regular 45°, threaded	0.4
b. 180° return bends	
180° return bend, flanged	0.2
180° return bend, threaded	1.5
c. Tees	
Line flow, flanged	0.2
Line flow, threaded	0.9
Branch flow, flanged	1.0
Branch flow, threaded	2.0
d. Union, threaded	0.08
***e. Valves**	
Globe, fully open	10
Angle, fully open	2
Gate, fully open	0.15
Gate, $\frac{1}{4}$ closed	0.26
Gate, $\frac{1}{2}$ closed	2.1
Gate, $\frac{3}{4}$ closed	17
Swing check, forward flow	2
Swing check, backward flow	∞
Ball valve, fully open	0.05
Ball valve, $\frac{1}{3}$ closed	5.5
Ball valve, $\frac{2}{3}$ closed	210