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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAM
SEMESTER II
2016/2017 SESSION

COURSE NAME	:	FLUID MECHANICS
COURSE CODE	:	BBM 30103
PROGRAMME CODE	:	BBA, BBD, BBG
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS.

THIS QUESTION PAPER NEEDS TO BE RETURNED AFTER THE EXAMINATION.

THIS EXAM PAPER CONTAINS **FOURTEEN (14)** PAGES INCLUSIVE OF COVER

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Q1 (a) Convert the following measurements to S.I. Units.

(i) 0.34 in. Hg

(2 marks)

(ii) 98°F

(2 marks)

(b) According to an empirical formula, the energy loss per unit weight of fluid flowing through a nozzle connected to a hose can be estimated by the formula

$$h = (0.04 \text{ to } 0.09)(D/d)^4 V^2/2g$$

where h is the energy loss per unit weight, D is the hose diameter, d the nozzle tip diameter, V the fluid velocity in the hose, and g the acceleration of gravity. Do you think this equation is valid in any system of units? Proof this validity and explain your answer.

(6 marks)

(c) Figure Q1(c) shows a manometer with pipe A contains gasoline ($SG = 0.7$), pipe B contains oil ($SG = 0.9$), and the manometer fluid is mercury. The initial differential reading is 0.30 m as shown in the figure. Determine the new differential reading if the pressure in pipe A is decreased 2.5 kPa, and the pressure in pipe B remains constant.

(10 marks)

Q2 (a) The inclined differential manometer as shown in Figure Q2(a) contains carbon tetrachloride ($\gamma = 99.5\ lb/ft^3$). Initially the pressure differential between pipes A and B, which contain a brine (S.G. = 1.1), is zero as illustrated in the figure. It is desired that the manometer give a differential reading of 12 in. (measured along the inclined tube) for a pressure differential of 0.1 psi. Determine the required angle of inclination, θ.

(10 marks)

(b) A structure is attached to the ocean floor as shown in Figure Q2(b). A 2 meter diameter hatch is located in an inclined wall and hinged on one edge. Determine the minimum air pressure, p_1, within the container that will open the hatch. Neglect the weight of the hatch and friction in the hinge.

(10 marks)

Q3 (a) Air flows steadily along a streamline from point (1) to point (2) with negligible viscous effects. The following conditions are measured: At point (1) $z_1 = 2$ m and $p_1 = 0$ kPa; at point (2) $z_2 = 10$ m, $p_2 = 20$ N/m^2, and $V_2 = 0$. Calculate the velocity at point (1).

(6 marks)

(b) Air flows steadily through a horizontal 4-in.-diameter pipe and exits into the atmosphere through a 3-in.-diameter nozzle. The velocity at the nozzle exit is 150 ft/s. Determine the pressure in the pipe if viscous effects are negligible.

(6 marks)

(c) Water flows steadily in the vertical variable-area pipe shown in Figure Q3(c). With assumption that the flow is inviscid and incompressible, determine the volumetric flowrate if the pressure in each of the gages reads 50 kPa.

(8 marks)

Q4 (a) Explain laminar, transitional and turbulent pipe flows using Reynolds number as a characteristic.

(6 marks)

(b) For oil ($SG = 0.86$, $\mu = 0.025$ Ns/m^2) flow of 0.3 m^3/s through a round pipe with diameter of 500 mm, determine the Reynolds number and indicate whether the flow is laminar or turbulent.

(6 marks)

(c) Water flows through a horizontal plastic pipe with a diameter of 0.2m at a velocity of 10cm/s.

(i) Determine the pressure drop per meter pipe using Moody chart.

(4 marks)

(ii) Calculate the power lost to the friction per meter of pipe.

(4 marks)

Q5 (a) The drag characteristics of a torpedo are to be studied in a water tunnel using a 1:5 scale model. The tunnel operates with freshwater at 20°C ($\nu = 1.004 \times 10^{-6}$ m^2/s), whereas the prototype torpedo is to be used in seawater at 15.6°C ($\nu = 1.17 \times 10^{-6}$ m^2/s). Calculate the velocity required in the water tunnel to simulate the behavior of the prototype moving with a velocity of 30 m/s.

(8 marks)

(b) The pressure rise, Δp, across a pump can be expressed as

$$\Delta p = f(D, \rho, \omega, Q)$$

where D is the impeller diameter, ρ the fluid density, ω the rotational speed (measured in per second) and Q the volumetric flowrate. Using the Buckingham Pi theorem, develop a suitable set of pi terms for this problem.

(12 marks)

-END OF QUESTIONS-

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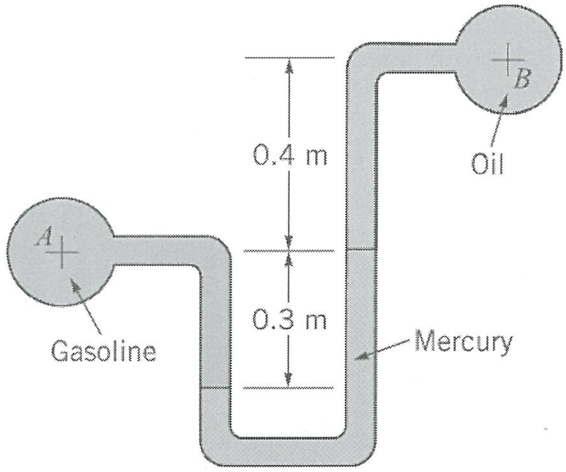

FIGURE Q1(c)

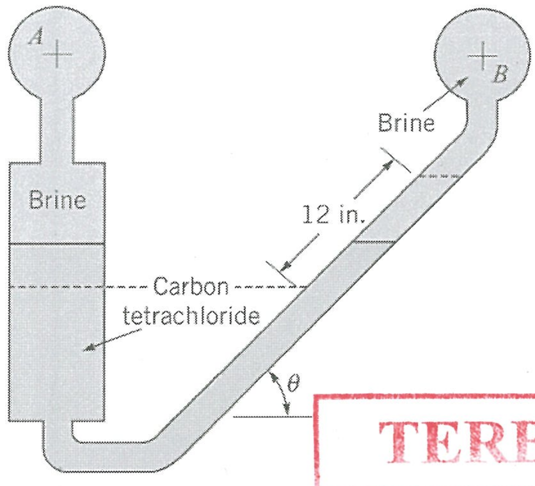

FIGURE Q2(a)

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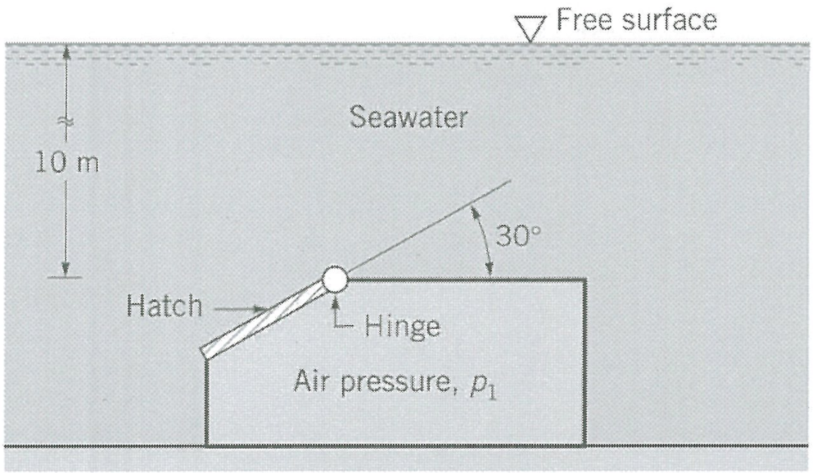

FIGURE Q2(b)

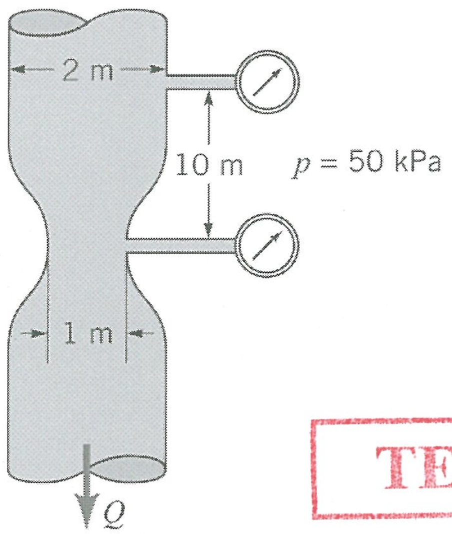

FIGURE Q3(c)

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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, $g = 9.81 m/s^2 = 32.2 ft/s^2$
$P_{atm} = 101.33 kPa(abs) = 2116.2 lb/ft^2(abs) = 14.7 psi(abs)$
$\rho_{air} = 1.225 kg/m^3 = 2.38 \times 10^{-3} slugs/ft^2$
$\gamma_{air} = 12.014 N/m^3 = 7.647 \times 10^{-2} lb/ft^3$

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

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

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

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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, $\Delta p = \frac{4l\tau_w}{D}$ τ_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, $\frac{1}{\sqrt{f}} = -2.0 \log(\frac{\epsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}})$

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

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

ϵ = 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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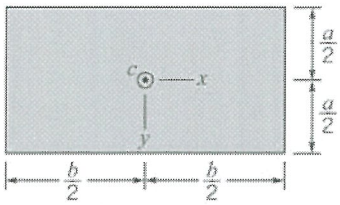
Geometric Properties of Common Shapes



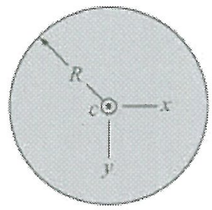
$A = ba$

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

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

$I_{xyc} = 0$

(*a*) Rectangle

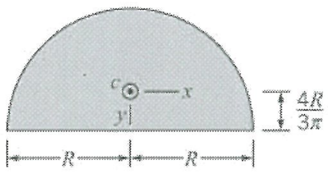


$A = \pi R^2$

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

$I_{xyc} = 0$

(*b*) Circle



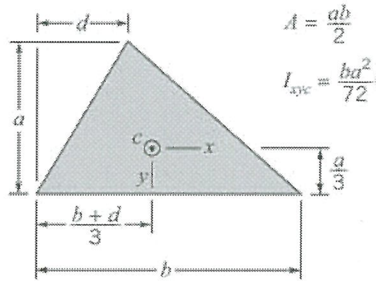
$A = \frac{\pi R^2}{2}$

$I_{xc} = 0.1098R^4$

$I_{yc} = 0.3927R^4$

$I_{xyc} = 0$

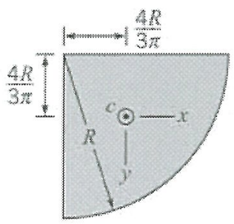
(*c*) Semicircle



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

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

(*d*) Triangle



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

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

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

(*e*) Quarter circle

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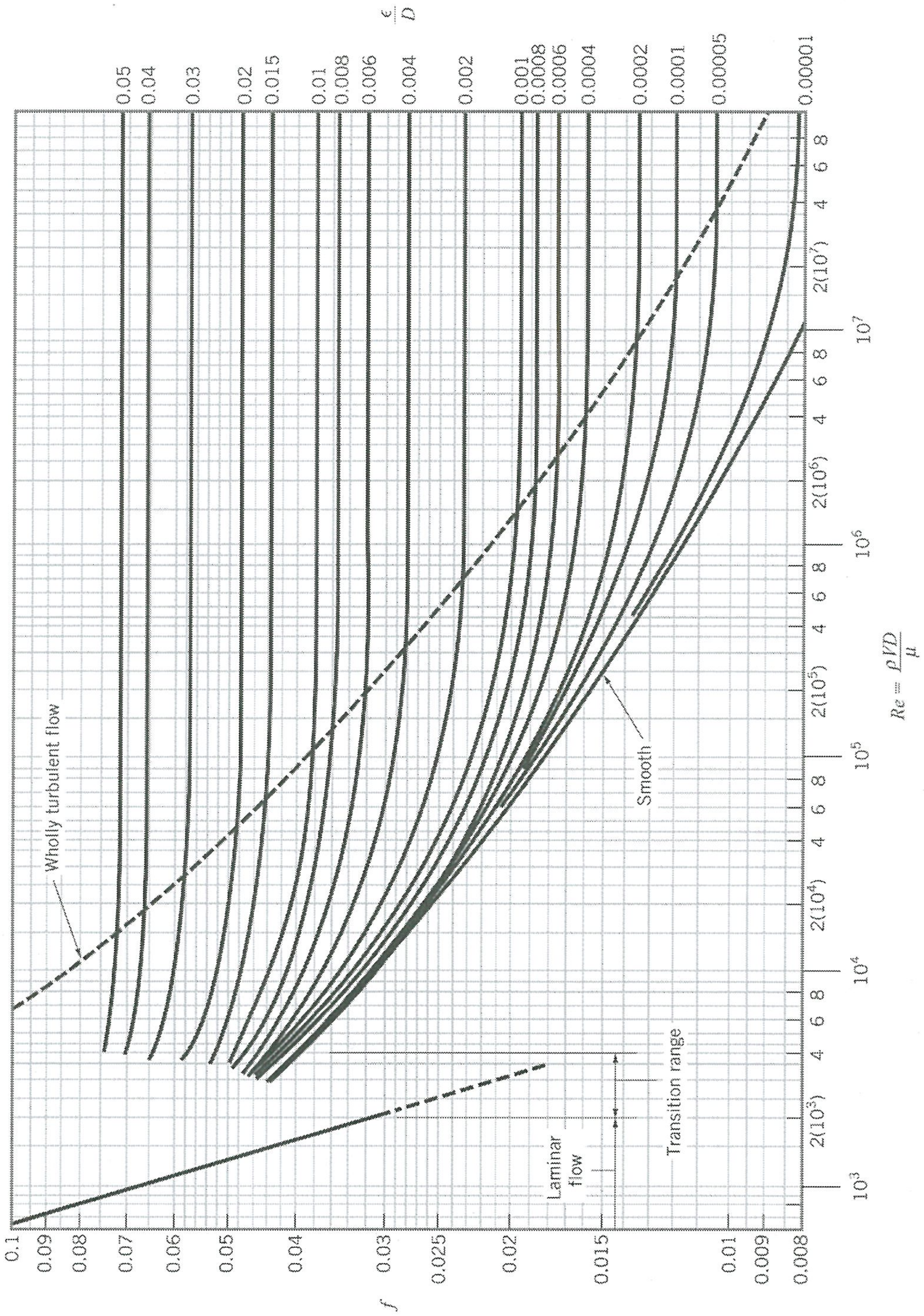
Moody Chart - Friction factor as a function of Reynolds Number and relative roughness for round pipes



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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