UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	FLUID MECHANICS
COURSE CODE	:	BBM 30103
PROGRAMME CODE	:	BBA / BBG
EXAMINATION DATE	:	JULY /AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK**. 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK.

THIS QUESTION PAPER CONSISTS OF **FIFTHTEEN (15)** PAGES

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

(i) 32 psi

(2 marks)

(ii) 90 mph

(2 marks)

(b) The volume rate of flow, Q, through a pipe containing a slowly moving liquid is given by the equation

$$Q = \frac{\pi R^4 \Delta p}{8\mu l}$$

where R is the pipe radius, Δp the pressure drop along the pipe, μ a fluid property called viscosity $(FL^{-2}T)$, and l the length of pipe. What are the dimensions of the constant $\pi/8$? Classify whether this equation is a general homogeneous equation.

(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 inverted U-tube manometer of **Figure Q2(a)** contains oil ($SG = 0.9$) and water as shown. The pressure differential between pipes A and B, $p_A - p_B$, is -5 kPa. Determine the differential reading, h.

(10 marks)

(b) The massless, 4-ft.-wide gate shown in **Figure Q2(b)** pivots about the frictionless hinge O. It is held in place by the 1500 lb counterweight W. Determine the water depth, h.

(10 marks)

Q3 (a) A pressurized tank of water as shown in **Figure Q3(a)** has a 10-cm-diameter orifice at the bottom, where water discharges to the atmosphere. The water level is 2.5 meters above the outlet. The tank air pressure above the water level is 250 kPa (absolute) while the atmospheric pressure is 100 kPa. Neglecting frictional effects, determine the initial discharge rate (in m^3/s) of water from the tank.

(10 marks)

(b) The water level in a tank as shown in **Figure Q3(b)** is 20m above the ground. A hose is connected to the bottom of the tank, and the nozzle at the end of those hose is pointed straight up. The tank is at sea level, and the water surface is open to the atmosphere. In the line leading from the tank to the nozzle is a pump, which increases the pressure of water. If the water jet rises to a height of 27m from the ground, determine the minimum pressure rise supplied by the pump to the water line.

(10 marks)

Q4 (a) Explain the flow characteristics of laminar, transitional and turbulent pipe flows using Reynolds number as an indicator.

(6 marks)

(b) Determine the Reynolds number for a type of oil ($SG = 0.85$, $\mu = 0.020$ Ns/m^2) that flow with flowrate of 0.45 m^3/s through a round pipe with diameter of 500 mm. Indicate the type of flow associated with your results.

(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. Power lost is defined by multiplying pressure and flowrate.

(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 ($\nu = 1.004\times10^{-6}$ m^2/s), whereas the prototype torpedo is to be used in seawater at 15.6°C ($\nu = 1.17\times10^{-6}$ 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 is the fluid density, ω is 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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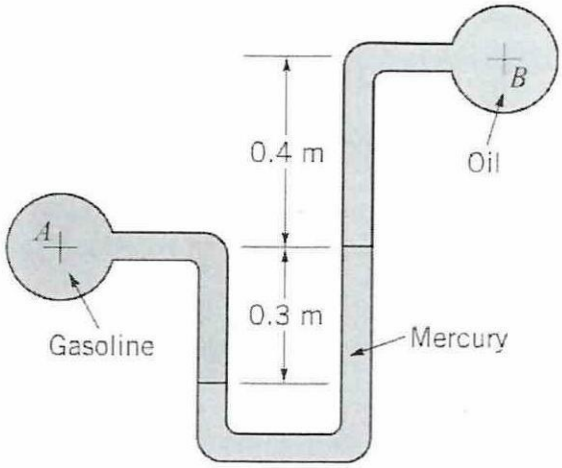

FIGURE Q1(c)

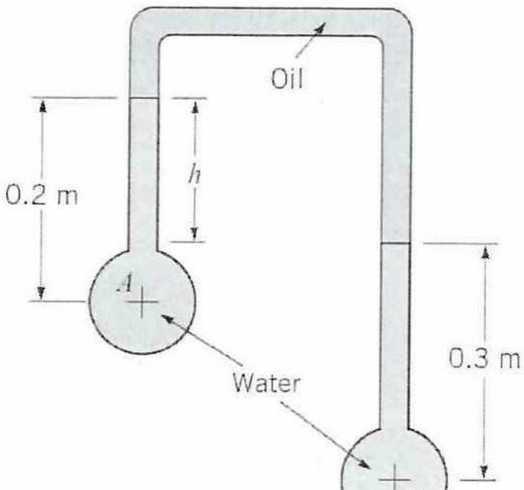

FIGURE Q2(a)

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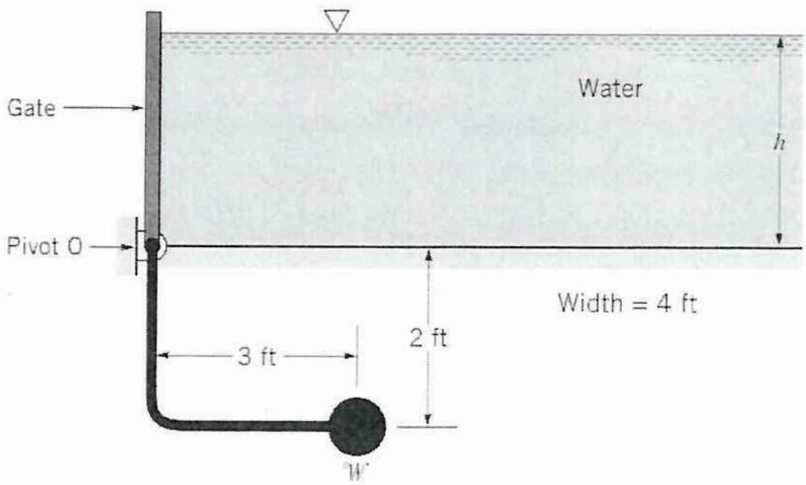

FIGURE Q2(b)

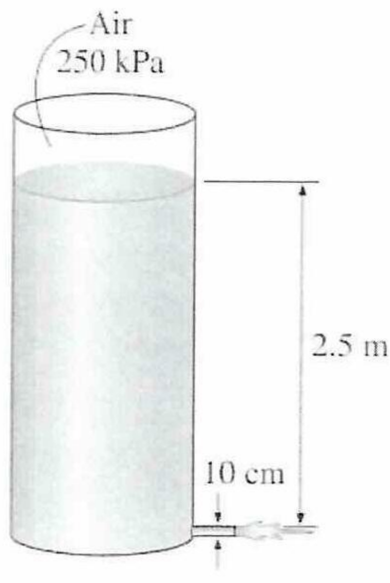

FIGURE Q3(a)

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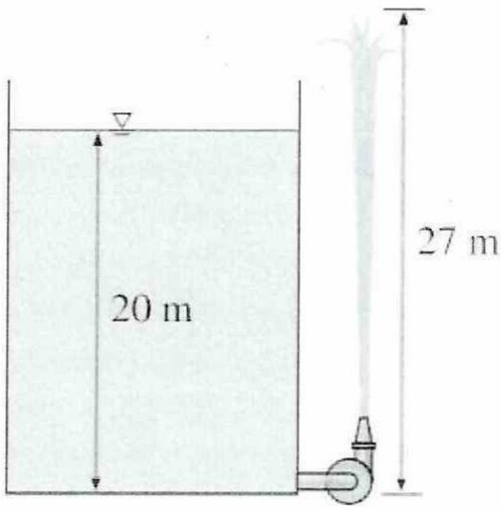

FIGURE Q3(b)

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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
$R = 287 J kg^{-1} K^{-1} = 4110 J kg^{-1} K^{-1}$

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

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

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

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, $Re = \frac{\rho VD}{\mu} = \frac{VD}{\upsilon}$ 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 · s/m^2	lb · 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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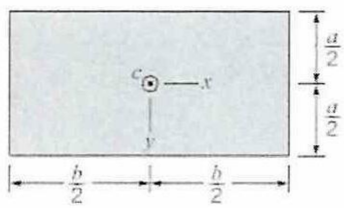
Geometric Properties of Common Shapes



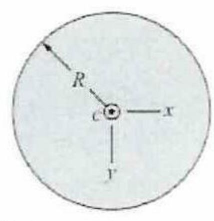
$A = ba$

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

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

$I_{xyc} = 0$

(*a*) Rectangle

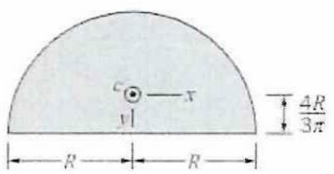


$A = \pi R^2$

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

$I_{xyc} = 0$

(*b*) Circle



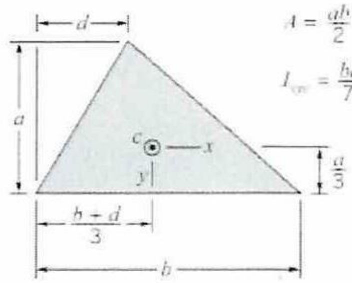
$A = \frac{\pi R^2}{2}$

$I_{xc} = 0.1098R^4$

$I_{yc} = 0.3927R^4$

$I_{xyc} = 0$

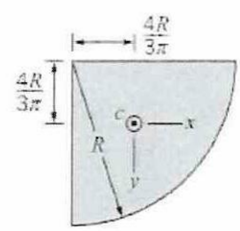
(*c*) Semicircle



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

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

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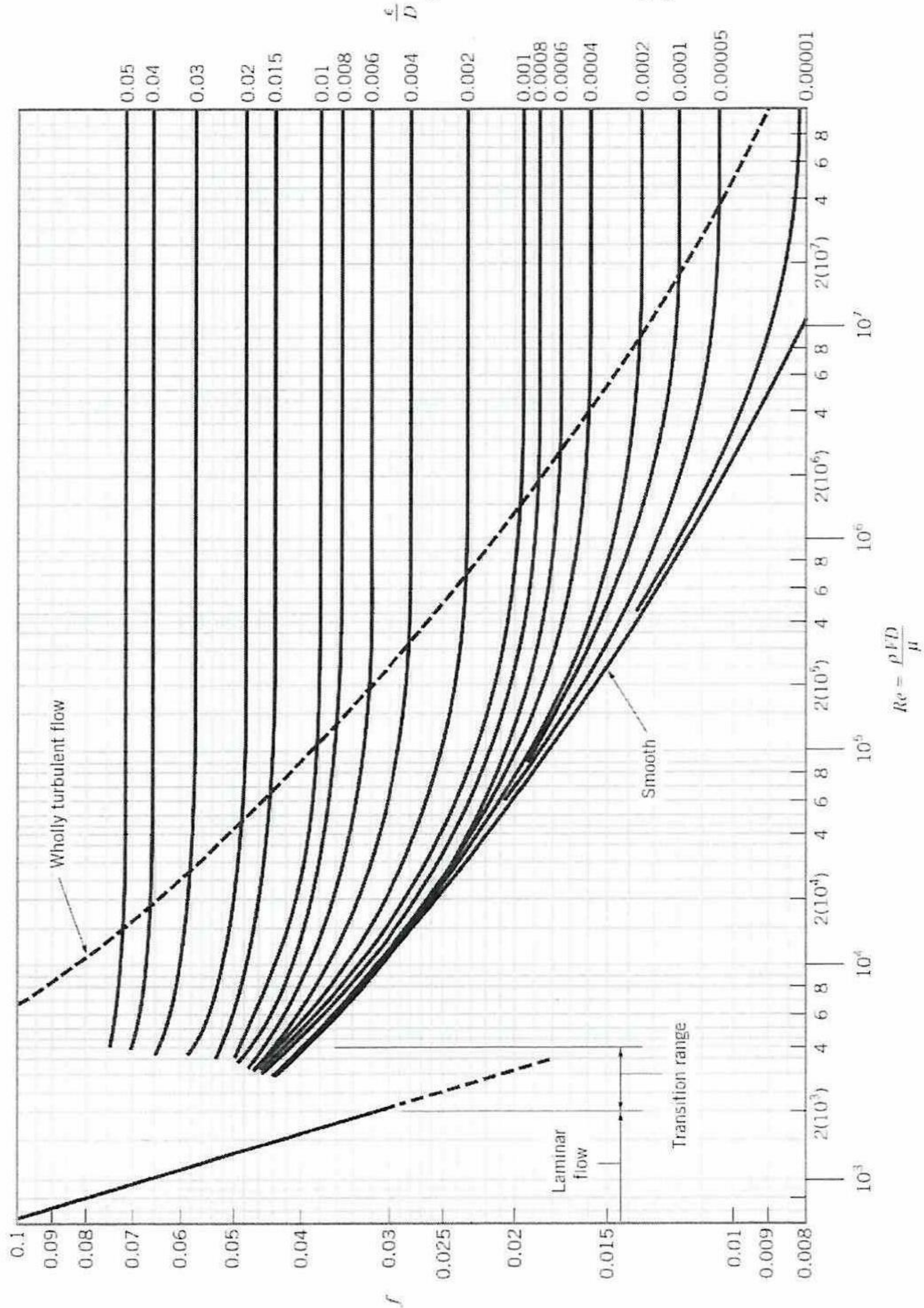
Moody Chart - Friction factor as a function of Reynolds Number and relative roughness for round pipes



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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