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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAM
SEMESTER I
SESSION 2016/2017

TERBUKA

COURSE NAME	:	FLUID MECHANICS
COURSE CODE	:	BBM 30103
PROGRAMME CODE	:	BBA / BBG
EXAMINATION DATE	:	DECEMBER 2016/ JANUARY 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) 289 BTU

(2 marks)

(ii) 100 Slugs

(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 π/8? Classify whether this equation is a general homogeneous equation.

(6 marks)

(c) An air-filled, hemispherical shell is attached to the ocean floor at a depth of 10m as shown in Figure Q1(c). A mercury barometer located inside the shell reads 765 mm Hg, and a mercury U-tube manometer designed to give the outside water pressure indicates a differential reading of 735 mm Hg as illustrated. Determine the atmospheric pressure at the ocean surface, if specific weight for sea water is 10.1 kN/m^3.

(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 2000 *lb* counterweight W. Determine the water depth, h.

(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) State the key difference between a model and a prototype.

(4 marks)

(b) A model of a submarine, 1:15 scale, is to be tested at 180 ft/s in a wind tunnel with standard sea-level air ($\upsilon = 1.57 \times 10^{-4}$ ft^2/s), while the prototype will be operated in seawater ($\upsilon = 1.26 \times 10^{-5}$ ft^2/s). Determine the speed of the prototype to ensure Reynolds number similarity.

(6 marks)

(c) A thin elastic wire is placed between rigid supports. A fluid flows past the wire, and it is desired to study the static deflection, δ, at the center of the wire due to the fluid drag. Assume that

$$\delta = f(l, d, \rho, \mu, V, E)$$

where l is the wire length, d the wire diameter, ρ the fluid density, μ the fluid viscosity, V the fluid velocity, and E the modules of elasticity of the wire material. Using the Buckingham Pi theorem, develop a suitable set of pi terms for this problem.

(10 marks)

-END OF QUESTIONS-

FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017
COURSE NAME : FLUID MECHANICS
PROGRAMME : BBA / BBG
COURSE CODE : BBM 30103

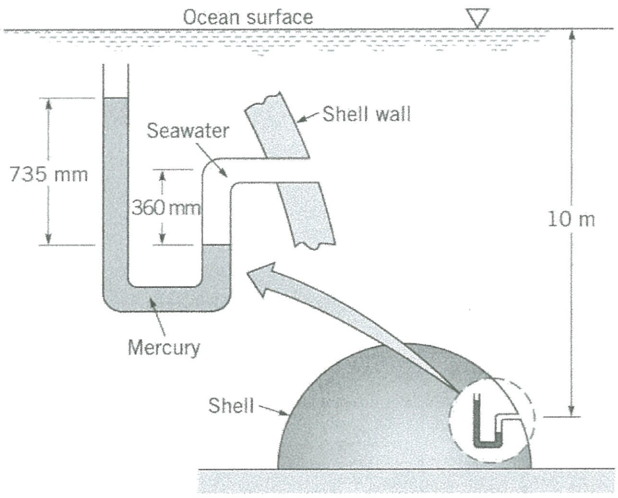

FIGURE Q1(c)

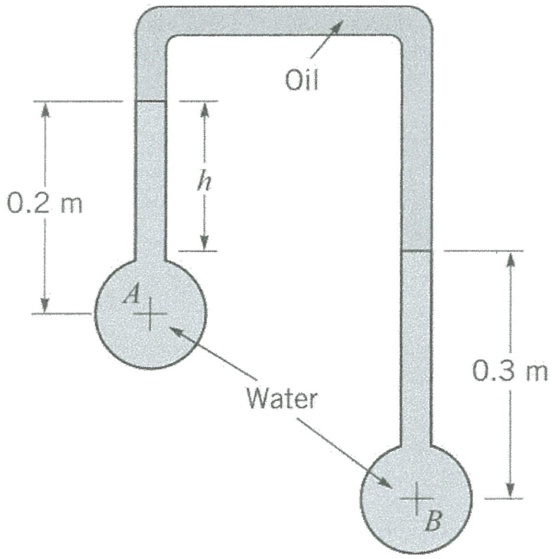

FIGURE Q2(a)

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SEMESTER / SESSION : SEMESTER I / 2016/2017 PROGRAMME : BBA / BBG
COURSE NAME : FLUID MECHANICS COURSE CODE : BBM 30103

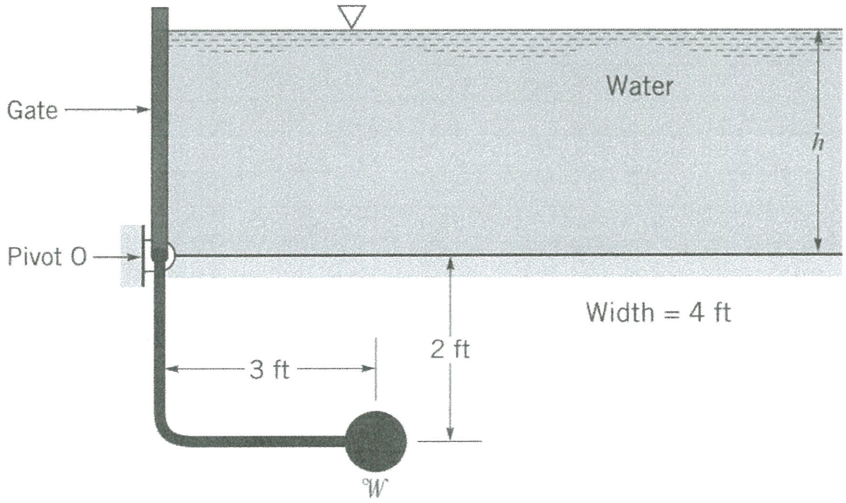

FIGURE Q2(b)

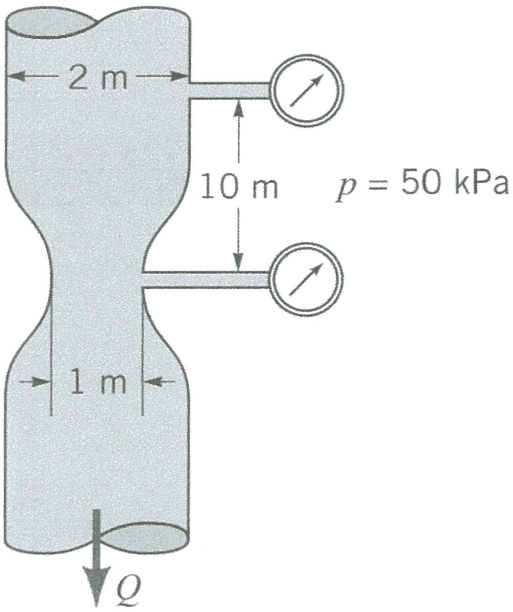

FIGURE Q3(c)

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SEMESTER / SESSION	: SEMESTER I / 2016/2017	PROGRAMME	: BBA / BBG
COURSE NAME	: FLUID MECHANICS	COURSE CODE	: BBM 30103

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

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

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 $\rho_1 = \rho_2$

FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017
COURSE NAME : FLUID MECHANICS
PROGRAMME : BBA / BBG
COURSE CODE : BBM 30103

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

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

ϵ = Pipe Equivalent Roughness

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FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017
COURSE NAME : FLUID MECHANICS
PROGRAMME : BBA / BBG
COURSE CODE : BBM 30103

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

FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017
COURSE NAME : FLUID MECHANICS
PROGRAMME : BBA / BBG
COURSE CODE : BBM 30103

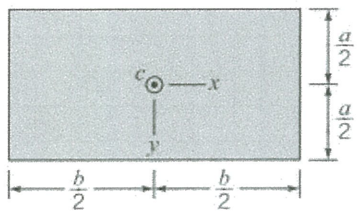
Conversion Tables

	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

FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017
COURSE NAME : FLUID MECHANICS
PROGRAMME : BBA / BBG
COURSE CODE : BBM 30103

Geometric Properties of Common Shapes



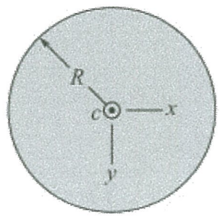
$A = ba$

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

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

$I_{xyc} = 0$

(a) Rectangle

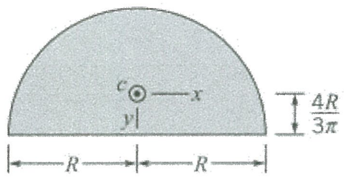


$A = \pi R^2$

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

$I_{xyc} = 0$

(b) Circle



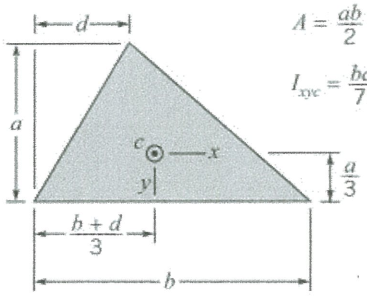
$A = \frac{\pi R^2}{2}$

$I_{xc} = 0.1098 R^4$

$I_{yc} = 0.3927 R^4$

$I_{xyc} = 0$

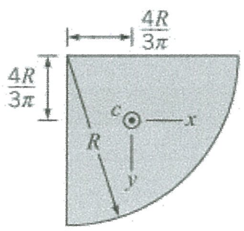
(c) Semicircle



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

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

(d) Triangle



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

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

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

(e) Quarter circle

FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017
COURSE NAME : FLUID MECHANICS

PROGRAMME : BBA / BBG
COURSE CODE : BBM 30103

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}

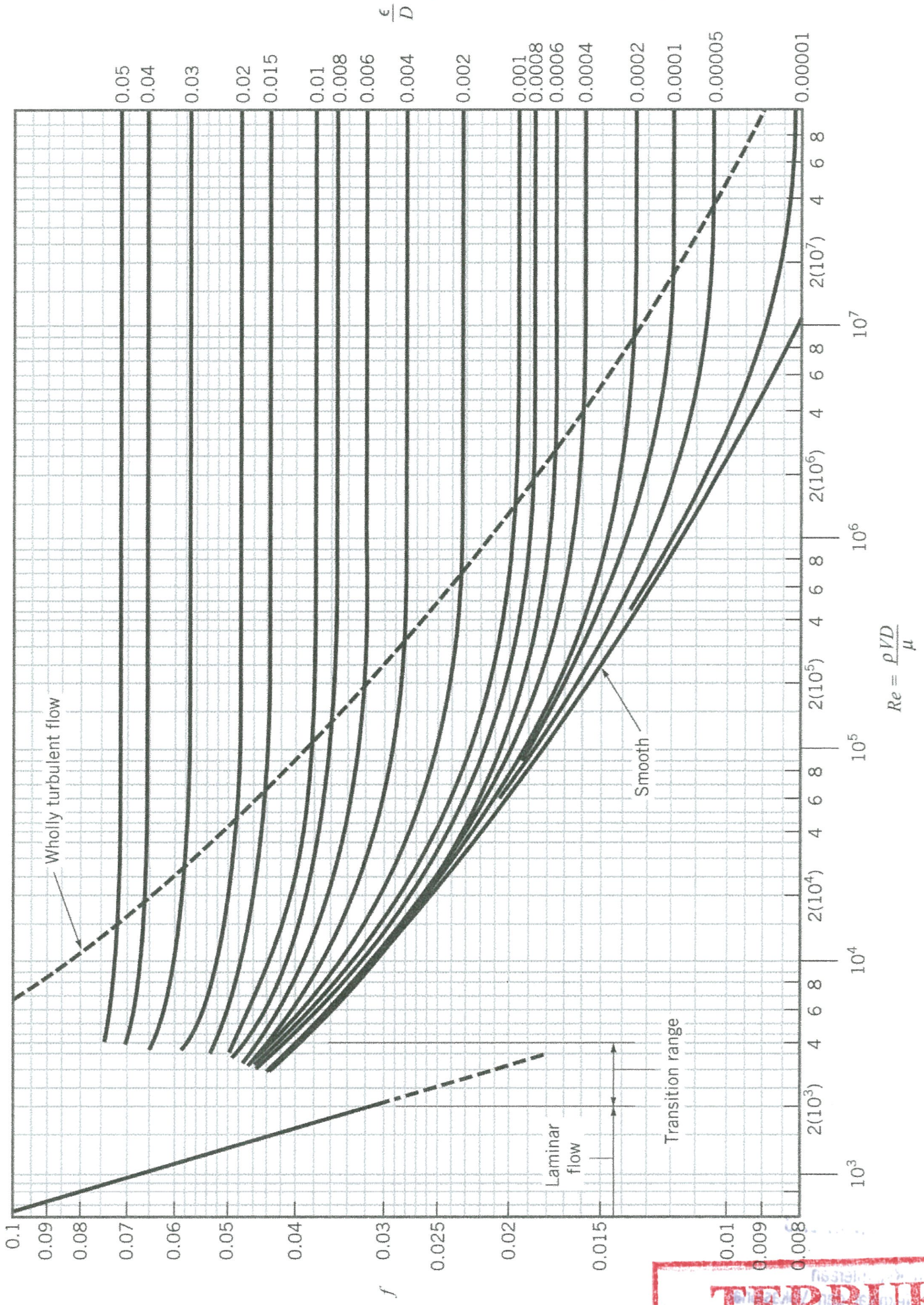
Equivalent Roughness for New Pipes

	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)

FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017 PROGRAMME : BBA / BBG
COURSE NAME : FLUID MECHANICS COURSE CODE : BBM 30103

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



FINAL EXAMINATION

SEMESTER / SESSION : SEMESTER I / 2016/2017
COURSE NAME : FLUID MECHANICS
PROGRAMME : BBA / BBG
COURSE CODE : BBM 30103

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