CONFIDENTIAL

UNIVERSITI KUALA LUMPUR
Malaysian Institute of Marine Engineering Technology

FINAL EXAMINATION
MARCH 2025 SEMESTER SESSION

SUBJECT CODE	:	**LGB22903**
SUBJECT TITLE	:	**FLUID MECHANICS 2**
PROGRAMME NAME **(FOR MPU: PROGRAMME LEVEL)**	:	**BACHELOR OF ENGINEERING TECHNOLOGY (OFFSHORE) WITH HONOURS**
TIME / DURATION	:	**9.00 AM - 12.00 PM** **(3 HOURS)**
DATE	:	**4 JULY 2025**

INSTRUCTIONS TO CANDIDATES

1. Please read **CAREFULLY** the instructions given in the question paper.
2. This question paper has information printed on both sides of the paper.
3. This question paper consists of **ONE (1) section** ONLY with SIX (6) questions answer **FOUR(4)** questions only.
4. Please write your answers on this answer booklet provided.
5. Answer **ALL** questions in English language **ONLY**.
6. *Answer should be written in blue or black ink except for sketches, graphics, and illustration*
7. Formula sheet and reference chart are attached with this questions paper

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THERE ARE 7 PAGES OF QUESTIONS, INCLUDING THIS PAGE.

INSTRUCTION: Answer FOUR (4) questions ONLY.
Please use the answer sheets provided.

Question 1 (CLO2)

(a) Briefly explain what is meant by fluid kinematics.

(2 marks)

(b) Determine the stagnation point in cartesian coordinate (x, y) for the following 2-dimensional velocity fields $\vec{V}$.

$$\vec{V} = (u, v) = (0.5 + 1.2x)\vec{\imath} + (-2.0 - 1.2y)\vec{\jmath}$$

(2 marks)

$$\vec{V} = (u, v) = (1 + 2.5x + y)\vec{\imath} + (-0.5 - 3x - 2.5y)\vec{\jmath}$$

(6 marks)

$$\vec{V} = (u, v) = (a^2 - (b - cx)^2)\vec{\imath} + (-2cby + 2c^2xy)\vec{\jmath}$$

(4 marks)

(c) Determine the value of constants in the following velocity fields $\vec{V}$ so that the flow is incompressible, and mass is conserved.

$$\vec{V} = (a_1x + b_1y + c_1z)\vec{\imath} + (a_2x + b_2y + c_2z)\vec{\jmath} + (a_3x + b_3y + c_3z)\vec{k}$$

(2 marks)

$$\vec{V} = a(x^2y + y^2)\vec{\imath} + (bxy^2)\vec{\jmath} + (cx)\vec{k}$$

(4 marks)

(d) Determine the acceleration components (a_x and a_y) at point (2,-1) in a steady, incompressible, two-dimensional flow velocity field given as:

$$\vec{V} = (u, v) = (1.85 + 2.33x + 0.656y)\vec{\imath} + (0.754 - 2.18x - 2.33y)\vec{\jmath}$$

(5 marks)

Question 2 (CLO2)

(a) In the linear momentum equation, the term summation of force (ΣF) is usually referred to these three (3) types of forces. State these three (3) types of forces.

(3 marks)

(b) In brief, explain the difference in concept between linear momentum equation and angular momentum equation.

(4 marks)

(c) A steam jet 35mm in diameter is discharged from a nozzle with a velocity of $80ms^{-1}$. The steam has a specific volume of $2.3m^3kg^{-1}$. This jet of steam strikes a stationary turbine blade which deflects the steam by 30^0 from the horizontal axis as shown below. Calculate the magnitude and direction of the resultant force on the blade. Ignore the effects of friction.

(18 marks)

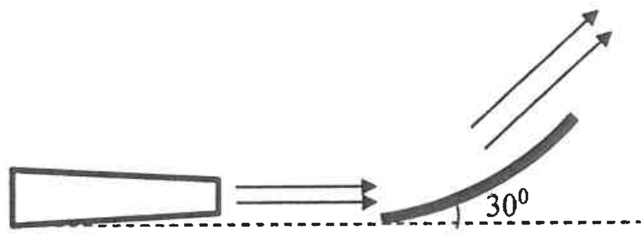


Figure 1: Steam jet striking a turbine blade

Question 3

(a) With the aid of diagram, describe rotodynamic pumps and give three (3) examples of such machines.

(8 marks)

(b) State three (3) factors that affect the net positive suction head (NPSH) in pumps.

(3 marks)

(c) State the difference between brake horsepower and water horsepower and define the efficiency of turbine in terms of these quantities.

(4 marks)

(d) The water pipe both upstream and downstream of the pump has an inner diameter of 2cm and is smooth (zero roughness). The minor loss coefficient of the sharp inlet is 0.5, each valve has a loss coefficient of 2.4, three elbows has a total loss coefficient of 0.9. The contraction at the exit has a diameter of 0.8cm and a loss coefficient of 0.15 at exit velocity. The total length of pipe is 8.75m and the change in elevation ($z_1 - z_2$) is 4.6m. Calculate the volume flowrate through the piping system shown in Figure 2 below assuming free delivery conditions ($H_{required} = 0$). Take ρ_{water} = 1000kg/m^3 and μ = 1.002 x 10^{-3}kg/ms.

(10 marks)

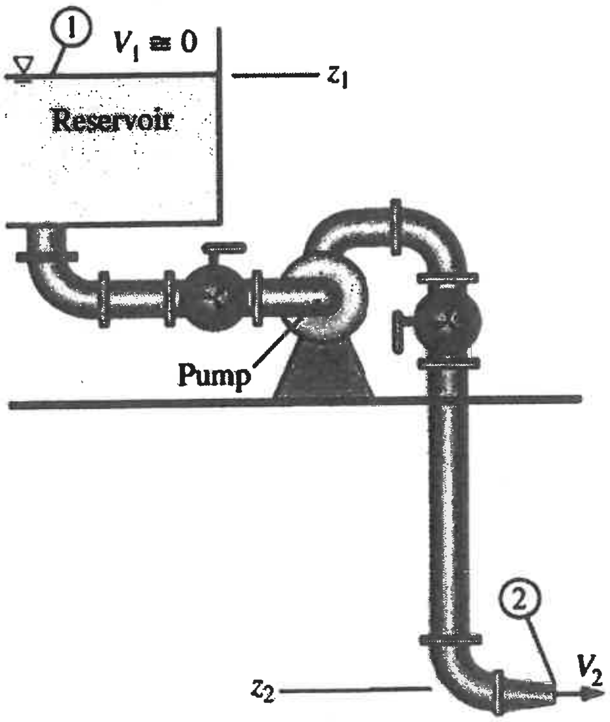


Figure 2: Reservoir piping system

Question 4

(a) State three main objectives of dimensional analysis.

(6 marks)

(b) State and briefly define the three (3) principles of similarity.

(6 marks)

(c) A fully developed Couette flow which is flow between two infinite parallel plates separated by a distance h, with the top plate moving and the bottom plate stationary as shown in Figure 3 below. The flow is steady, incompressible, and two-dimensional in the xy-plane. By using Method of Repeating Variables and the Buckingham Pi Theorem, determine the dimensionless terms (π) for the following dimensional relationship:

$u = f(\mu, v, h, \rho, y)$

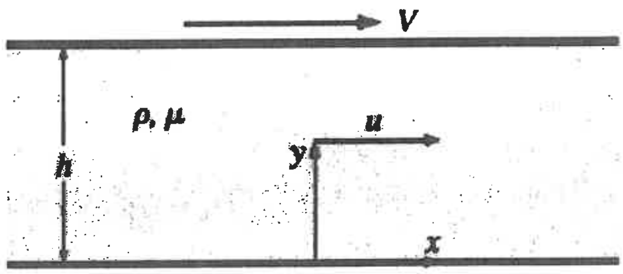


Figure 3: Fully developed Couette flow

Given:

u = fluid velocity in the x-direction (m/s)

μ = dynamic viscosity (Pas)

v = velocity of the top plate (m/s)

h = distance between top and bottom plates (m)

ρ = density of fluid (kg/m^3)

y = distance from bottom plate (m)

(13 marks)

Question 5

(a) In a river flowing at a velocity of $1.5ms^{-1}$, a motorboat travels upstream at $9ms^{-1}$ relative to the land. The boat is powered by a water jet system that sucks in water at the bow and discharges it at the stern. The discharge velocity is $18ms^{-1}$ relative to the boat with a volume flowrate of $0.15m^3s^{-1}$. The engine produces 21kW of power. Take $\rho_{water} = 1000kgm^{-3}$.

(i) Calculate the propulsion force of the water jet system.

(3 marks)

(ii) Calculate the propulsion force on the motorboat.

(4 marks)

(iii) Determine the water jet system overall efficiency in percentage. Take efficiency (η) in percentage as $\eta = \frac{output\ force}{input\ force} \times 100\%$.

(2 marks)

(b) A 75mm diameter jet has a velocity of 33.5m/s. It strikes a blade moving in the same direction at 21.3m/s. The deflection angle of the blade is 150^0. Friction further reduces the relative velocity of water with respect to the blade by 1.5m/s. Determine the force exerted by the water on the blade.

(16 marks)

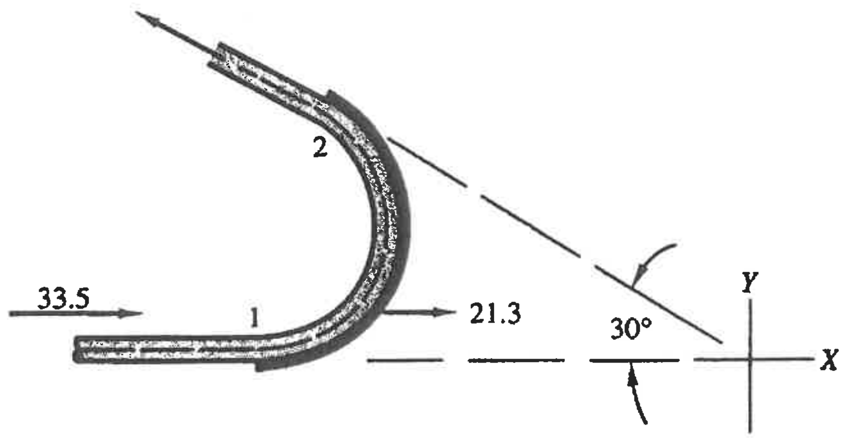


Figure 4: Jet flow striking a moving plate

Question 6

(a) One of the important parameters in the analysis of fluid flow is Reynolds Number (Re). State three (3) factors that influence Reynolds Number.

(3 marks)

(b) The two (2) flow regimes namely laminar and turbulent have many different properties when compared to each other. From the viewpoint of flow over flat plate, describe in your own words and with the aid of diagrams, the boundary layer (δ) acting on a flat plate, and state the factors affecting the flow regime within the boundary layer to change from laminar to turbulent.

(10 marks)

(c) A train is 110m long, 2.75m wide and with sides 2.75m high is travelling at a velocity 160km/h. Assuming that the skin friction drag on sides and top of the train can be approximated to a flat plate that is 110m long and 8.25m wide and taking the density of air as $\rho_{air} = 1.225 \frac{kg}{m^3}$, $\mu_{air} = 1.790 \times 10^{-5} Pas$, determine the following:

(i) The drag force (F_D) exerted by the air on the frontal area of the train.

(7 marks)

(ii) The boundary layer thickness (δ) at the location $x = 110m$ (at the end of the train).

(2 marks)

(iii) The power (P) needed to overcome the drag force (F_D).

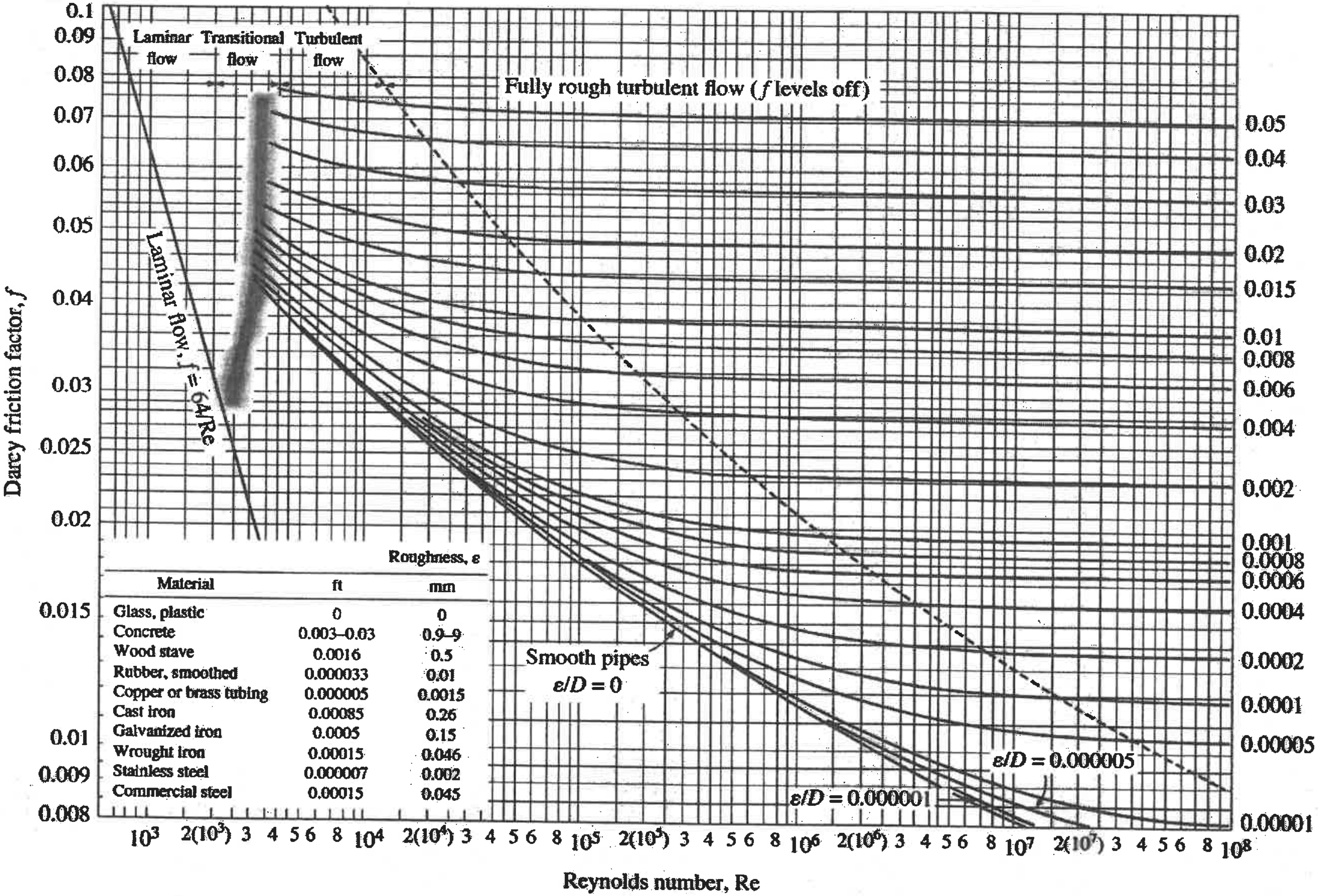
(3 marks)

END OF QUESTION PAPER

Fluid Statics	$P = \frac{F}{A}$
	$P = \rho g h$
	$\frac{F_1}{A_1} = \frac{F_2}{A_2}$
	$\tau = \mu \frac{dv}{dy}$
Fluid Kinematics & Dynamics	$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$
	$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$
	$A_1 v_1 = A_2 v_2$ (incompressible fluid)
	$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$ (incompressible fluid)
	$\vec{\omega} = \frac{1}{2}\left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right)\vec{i} + \frac{1}{2}\left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right)\vec{j} + \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)\vec{k}$
	$\varepsilon_{xx} = \frac{\partial u}{\partial x} \quad \varepsilon_{yy} = \frac{\partial v}{\partial y} \quad \varepsilon_{zz} = \frac{\partial w}{\partial z}$
	$\varepsilon_{xy} = \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) \quad \varepsilon_{zx} = \frac{1}{2}\left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}\right) \quad \varepsilon_{yz} = \frac{1}{2}\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)$
	$\Sigma F_x = \dot{m}(v_{2x} - v_{1x})$ $\Sigma F_y = \dot{m}(v_{2y} - v_{1y})$ $\Sigma F_z = \dot{m}(v_{2z} - v_{1z})$
	$a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}$ $a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}$ $a_z = \frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}$
	$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) = -\frac{\partial P}{\partial x} + \rho g_x + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$ $\rho\left(\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right) = -\frac{\partial P}{\partial y} + \rho g_y + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right)$ $\rho\left(\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right) = -\frac{\partial P}{\partial z} + \rho g_z + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right)$

Head Loss	$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 + H_{pump} = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + H_L + H_{turbine}$
	$H_L = f\frac{L}{D}\left(\frac{v^2}{2g}\right)$ (pipe friction factor)
	$H_L = \Sigma K\left(\frac{v^2}{2g}\right)$ (losses in fittings)
	$H_L = \left(f\frac{L}{D} + \Sigma K\right)\left(\frac{v^2}{2g}\right)$ (total head loss in system)
	$Re = \frac{\rho v D}{\mu} = \frac{vD}{\upsilon}$
	$Re \leq 2000$ (laminar) $Re \geq 4000$ (turbulent) (for flow in pipes)
	$f = \frac{64}{Re}$ (laminar flow)
	$f = 0.0055\left[1 + \left(20000\varepsilon_R + \frac{1 \times 10^6}{Re}\right)^{\frac{1}{3}}\right]$ (turbulent flow)
Flow Over Immersed Bodies	$C_D = \frac{F_D}{\frac{1}{2}\rho v^2 A}$
	$C_L = \frac{F_L}{\frac{1}{2}\rho v^2 A}$
	$C_D = C_{D,friction} + C_{D,pressure}$ $F_D = F_{D,friction} + F_{D,pressure}$
	$Re_L = \frac{\rho v L}{\mu} = \frac{vL}{\upsilon}$
	$Re_x = \frac{\rho v x}{\mu} = \frac{vx}{\upsilon}$
	$\delta = \frac{4.91(x)}{Re_x^{\frac{1}{2}}}$ $C_{f,x} = \frac{0.664}{Re_x^{\frac{1}{2}}}$ (for laminar flow, $Re \leq 5 \times 10^5$) *flow over flat plate at location x
	$\delta = \frac{0.38(x)}{Re_x^{\frac{1}{5}}}$

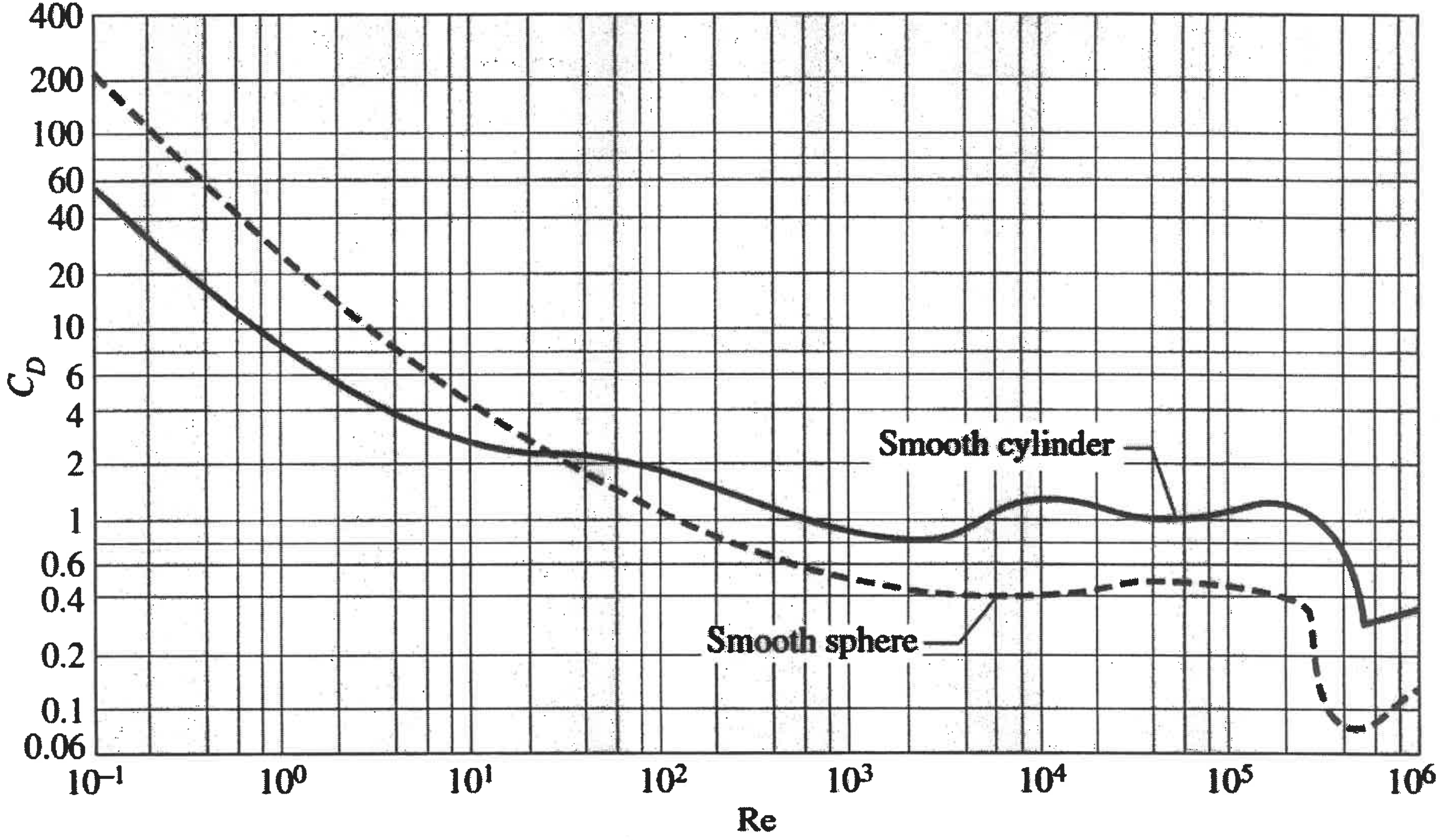
	$C_{f,x} = \frac{0.059}{Re_x^{\frac{1}{5}}}$ (for turbulent flow, $5 \times 10^5 \leq Re \leq 1 \times 10^7$) *flow over flat plate at location x
	$C_f = \frac{1.33}{Re_L^{\frac{1}{2}}}$ (for laminar flow, $Re \leq 5 \times 10^5$) *flow over the entire plate of length L
	$C_f = \frac{0.074}{Re_L^{\frac{1}{5}}}$ (for turbulent flow, $5 \times 10^5 \leq Re \leq 1 \times 10^7$) *flow over the entire plate of length L
Buoyancy	$F_B = W \rightarrow \rho_f g V_{sub} = \rho_{avg.body} g V_{total}$
Turbomachinery	$\dot{V} = \frac{\dot{m}}{\rho}$
	$H = \left(\frac{P}{\rho g} + \frac{v^2}{2g} + z\right)_{out} - \left(\frac{P}{\rho g} + \frac{v^2}{2g} + z\right)_{in}$ $H = EGL_{out} - EGL_{in}$
	$\dot{W}_{water\ horsepower} = \dot{m}gH = \rho g \dot{V} H = \dot{m}\frac{\Delta P}{\rho} = \dot{V}\Delta P$
	$bhp = \dot{W}_{shaft} = \omega T_{shaft}$
	$\eta_{pump} = \frac{\dot{W}_{water\ horsepower}}{W_{shaft}} = \frac{\dot{W}_{water\ horsepower}}{bhp} = \frac{\rho g \dot{V} H}{\omega T_{shaft}}$
	$H_{required} = h_{pump,u} = \frac{P_2 - P_1}{\rho g} + \frac{\alpha_2 {v_2}^2 - \alpha_1 {v_1}^2}{2g} + (z_2 - z_1) + H_{L,total}$
	$NPSH = \left(\frac{P}{\rho g} + \frac{v^2}{2g}\right)_{pump\ inlet} - \frac{P_v}{\rho g}$
	$N_U = \frac{N_1 d_1}{\sqrt{z_1}} = \frac{N_2 d_2}{\sqrt{z_2}}$



Material	Roughness, ε ft	Roughness, ε mm
Glass, plastic	0	0
Concrete	0.003–0.03	0.9–9
Wood stave	0.0016	0.5
Rubber, smoothed	0.000033	0.01
Copper or brass tubing	0.000005	0.0015
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Wrought iron	0.00015	0.046
Stainless steel	0.000007	0.002
Commercial steel	0.00015	0.045

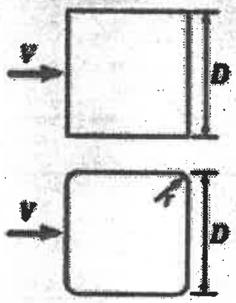
FIGURE A–12

The Moody chart for the friction factor for fully developed flow in circular pipes for use in the head loss relation $h_L = f\frac{L}{D}\frac{V^2}{2g}$. Friction factors in the turbulent flow are evaluated from the Colebrook equation $\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right)$.


400
200
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
0.06
C_D
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
10^6
Re
Smooth cylinder
Smooth sphere

Drag coefficients C_D of various two-dimensional bodies for Re > 10^4 based on the frontal area $A = bD$, where b is the length in direction normal to the page (for use in the drag force relation $F_D = C_D A \rho V^2/2$ where V is the upstream velocity)

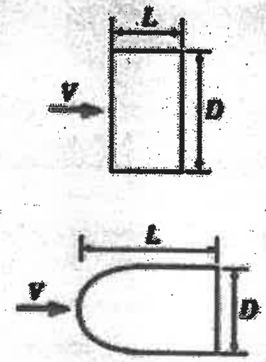
Square rod



Sharp corners: $C_D = 2.2$

Round corners ($r/D = 0.2$): $C_D = 1.2$

Rectangular rod



Sharp corners:

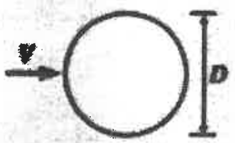
L/D	C_D
0.0*	1.9
0.1	1.9
0.5	2.5
1.0	2.2
2.0	1.7
3.0	1.3

*Corresponds to thin plate

Round front edge:

L/D	C_D
0.5	1.2
1.0	0.9
2.0	0.7
4.0	0.7

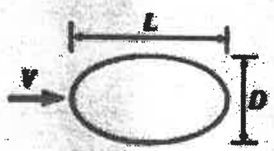
Circular rod (cylinder)



Laminar: $C_D = 1.2$

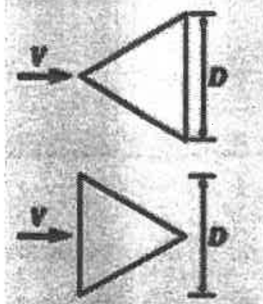
Turbulent: $C_D = 0.3$

Elliptical rod



L/D	C_D Laminar	C_D Turbulent
2	0.60	0.20
4	0.35	0.15
8	0.25	0.10

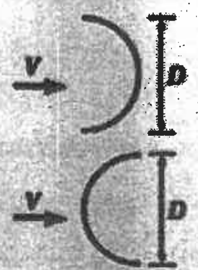
Equilateral triangular rod



$C_D = 1.5$

$C_D = 2.0$

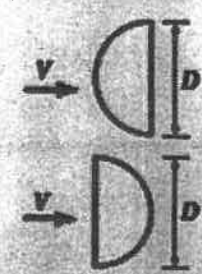
Semicircular shell



$C_D = 2.3$

$C_D = 1.2$

Semicircular rod

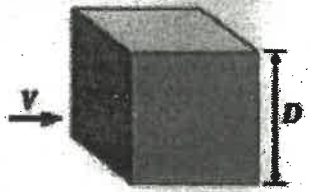


$C_D = 1.2$

$C_D = 1.7$

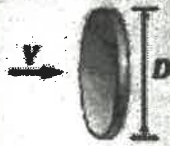
Representative drag coefficients C_D for various three-dimensional bodies based on the frontal area for Re > 10^4 unless stated otherwise (for use in the drag force relation $F_D = C_D A \rho V^2/2$ where V is the upstream velocity)

Cube, $A = D^2$



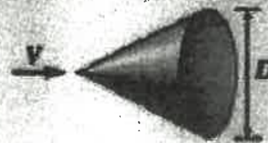
$C_D = 1.05$

Thin circular disk, $A = \pi D^2/4$



$C_D = 1.1$

Cone (for $\theta = 30°$), $A = \pi D^2/4$



$C_D = 0.5$

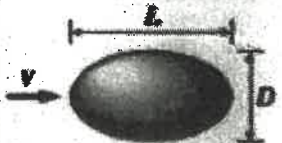
Sphere, $A = \pi D^2/4$

Laminar: Re ≲ 2×10^5, $C_D = 0.5$

Turbulent: Re ≳ 2×10^6, $C_D = 0.2$

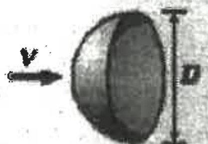
See Fig. 11–36 for C_D vs. Re for smooth and rough spheres.

Ellipsoid, $A = \pi D^2/4$

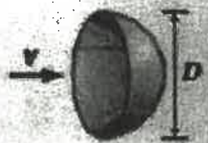


L/D	C_D Laminar Re ≲ 2×10^5	C_D Turbulent Re ≳ 2×10^6
0.75	0.5	0.2
1	0.5	0.2
2	0.3	0.1
4	0.3	0.1
8	0.2	0.1

Hemisphere, $A = \pi D^2/4$



$C_D = 0.4$



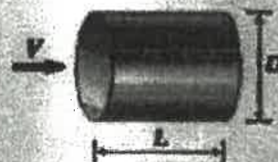
$C_D = 1.2$

Finite cylinder, vertical, $A = LD$

L/D	C_D
1	0.6
2	0.7
5	0.8
10	0.9
40	1.0
∞	1.2

Values are for laminar flow (Re ≲ 2×10^5)

Finite cylinder, horizontal, $A = \pi D^2/4$

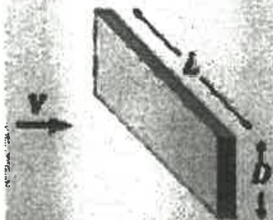


L/D	C_D
0.5	1.1
1	0.9
2	0.9
4	0.9
8	1.0

Streamlined body, $A = \pi D^2/4$

$C_D = 0.04$

Rectangular plate, $A = LD$



$C_D = 1.10 + 0.02\,(L/D + D/L)$ for $1/30 < (L/D) < 30$