ENGG2500 Fluid Mechanics for Engineers

UNSW SYDNEY · TERM 3 2026 · OPEN-BOOK EXAM SHEET

Full guide + ask Sia about ENGG2500

SIDE 1 · METHODS

Final: 55% · two hours · all lecture materials

SKETCH → ASSUMPTIONS → BALANCE → UNITS → DIRECTION

00 Exam map

COURSE OUTLINE · T3 2026

Final 55% | Online | Midterm | Lab 15%

"Open book. The exam will take place during the official exam period." (ENGG2500 Course Outline, Term 3 2026)

PROBLEM CUE	START WITH	THEN COUPLE
Depth / manometer	Hydrostatics	Pressure reference
Floating / gate	Force + moment	Line of action
Area / branch flow	Continuity	Signed flux
Pressure / speed / pump	Energy	Continuity + loss
Jet / bend / support	Momentum	Continuity, energy
Scale model	Buckingham Π	Match force ratio
Pipe Δp / h_L	Re → f → loss	Network energy
Torque	Angular momentum	rV_θ
External drag	$Re + C_D$	Area convention

EXAM TIP *Write the most general balance first; remove a term only beside the physical assumption that removes it.*

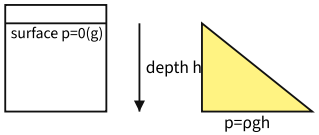
01 Properties + hydrostatics C1

PROPERTY / PRESSURE LEDGER

$\rho = m/V \quad \nu = \mu/\rho \quad \tau = \mu(du/dy)$

$p_{abs} = p_{gauge} + p_{atm}$

$p_2 - p_1 = \rho g(z_1 - z_2)$



Constant-density static liquid: pressure grows linearly with downward depth.

MANOMETER MOVE	PRESSURE TERM
Down through fluid i	$+\rho_i g\Delta h$
Up through fluid i	$-\rho_i g\Delta h$
Across interface	p continuous; change ρ
Horizontal, same static fluid	No pressure change

Absolute pressure is compulsory for vapour-pressure or gas-relation comparisons. Vessel shape does not alter pressure at a fixed elevation in one connected resting fluid.

PROPERTY AND MODEL CHECKS

QUANTITY	PHYSICAL ROLE	SI / DECISION
Density ρ	Mass, inertia, weight	kg/m^3
Dynamic viscosity μ	Newtonian shear response	Pa·s
Kinematic viscosity ν	Viscous diffusion / inertia	m^2/s; $\nu=\mu/\rho$

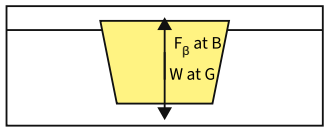
HYDROSTATIC SOLUTION CHAIN

02 Resultants + buoyancy C2

MAGNITUDE, LOCATION, EQUILIBRIUM

$F_R = p_c A \quad F_B = \rho g V_{disp}$

$\sum F = 0 \quad \sum M = 0$



Buoyancy acts through displaced-volume centroid; weight acts through the body's centre of gravity.

TASK	DO	DO NOT
Plane surface	Use centroid pressure for F_R	Put force at centroid automatically
Gate/support	Locate centre of pressure, then moments	Merge magnitude and lever arm
Floating body	Balance W, F_B, cable/support	Assume B and G coincide
Initial stability	Positive metacentric height → restoring tendency	Infer stability from force balance alone

Centre of pressure lies deeper than the centroid for a non-horizontal plane because the lower area carries greater pressure.

Accelerating tank: combine gravity with inertial acceleration; the free surface is perpendicular to the effective-gravity direction.

DIRECTION CHECK *A downward restraint means buoyancy exceeds weight; support a heavy body upward when weight exceeds buoyancy.*

03 Continuity C3

MASS CONSERVATION

$d/dt \int_{CV}\rho\, dV + \int_{CS}\rho V\cdot n\, dA = 0$

$Q = A\bar{V} \quad \dot{m} = \rho Q$ $A_1V_1 = A_2V_2$ only after steady + incompressible + 1-D.



streamtube side: V·n=0

Average velocity preserves flux; it does not claim a uniform local profile.

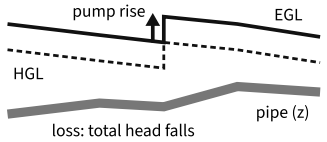
BEFORE SIMPLIFYING	MEANING
CV + outward normals	Outflow +; inflow −
Accumulation	Retain for filling/draining
Steady	Accumulation zero; branches still sum
Constant density	May cancel ρ from every flux term
Several branches	Close the signed ledger

04 Energy method C4

GENERAL MECHANICAL-ENERGY BALANCE

$p_1/(\rho g) + V_1^2/(2g) + z_1 + h_p - h_t - h_L = p_2/(\rho g) + V_2^2/(2g) + z_2$

ENDPOINT / ELEMENT	KNOWN SIMPLIFICATION
Large open reservoir surface	$p_g=0$; V≈0
Free jet	$p_g=0$; retain $V^2/2g$
Pipe tap	Retain p, V, z
Pump	$+h_p$, energy into fluid
Turbine	$-h_t$, energy out
Passive path	$-h_L$; h_L positive



loss: total head falls

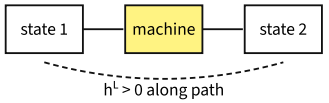
EGL = HGL + $V^2/(2g)$; pump raises both, losses make total head fall.

POWER + CAVITATION

$P_{hyd} = \rho g Q h_p$

Compare local absolute pressure with vapour pressure.

Bernoulli special case: steady, effectively incompressible, negligible viscous loss, no shaft work, appropriate streamline. Otherwise retain the omitted terms in the general equation.



$h^L > 0$ along path

Point choice is modelling: retain every machine and loss between the two sections.

ENERGY AUDIT BEFORE ARITHMETIC

1. Sketch actual flow path; choose two sections where p, V or z is known or requested.
2. Fix one elevation datum. List p/(ρg), $V^2/(2g)$ and z at both sections.
3. Mark every pump, turbine and loss element physically between the sections.
4. Write the full equation. Cancel only equal atmospheric pressures, negligible reservoir speeds or absent devices, each with a reason.
5. Use continuity separately when area change makes V unknown; convert head to pressure or power only after the head ledger closes.

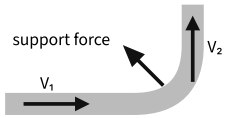
AFTER SOLVING	REQUIRED PHYSICAL PICTURE
Passive pipe	EGL falls in flow direction
Enlargement	V head may fall and p head recover; total head still falls
Pump	Discrete upward grade-line jump
Turbine	Discrete downward grade-line jump
Negative solved loss	Recheck flow direction or missing machine

05 Linear momentum C5

STEADY ONE-INLET / ONE-OUTLET

$\sum F = \dot{m}(V_{out} - V_{in})$ (vector)

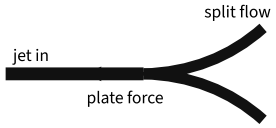
Pressure force acts inward on each control-surface cut.



same speed; ΔV≠0

Resolve velocity, pressure, weight and wall force into declared axes.

SEQUENCE	CHECKPOINT
1 Control volume	Fixed frame; axes; outward normals
2 Continuity	$\dot{m}$ and every section velocity
3 Force ledger	Pressure inward; fluid weight if material
4 Components	One momentum equation per axis
5 Requested body	Reverse only for force on hardware



Symmetric split cancels vertical momentum change; force follows the lost horizontal component.

A negative component is directional information, not an impossible force.

06 Buckingham Π + similarity C6

COUNT, BUILD, INTERPRET

No. independent groups = n - r

Re = ρVL/μ = VL/ν



check count, dimensions, independence

Algebra cannot recover a governing variable omitted from the physical variable list.

REPEATING VARIABLES MUST...	MODEL STATEMENT
Contain every base dimension	Geometric similarity first
Be dimensionally independent	Match dominant force ratio
Not form a Π group alone	Quantify any unmatched group

For each non-repeating variable, multiply by powers of the repeaters, set M, L and T exponents to zero, solve, then verify dimensions and group count. Different valid repeating sets can be algebraically equivalent. Interpret every group physically.

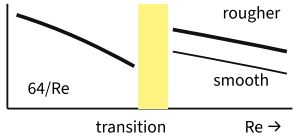
07 Internal pipe flow C7

REGIME → RESISTANCE → LOSS

$Re = \rho VD/\mu$ relative roughness = ε/D

$h_f = f(L/D)V^2/(2g) \quad \Delta p = \rho g h_f$

Laminar circular pipe: f = 64/Re



Moody entry needs Re and ε/D; chart output is the Darcy friction factor.

INPUT	REQUIRED CHECK
Q and D	$A=\pi D^2/4$; V=Q/A
ρ, μ, temperature	Use operating properties; calculate Re
Laminar	Use 64/Re
Turbulent	Use Re and ε/D on chart/correlation
Factor convention	Darcy = 4 × Fanning
Unknown flow	Guess f → solve V → update Re → repeat



Developed means profile shape stops changing downstream; pressure may still fall.

No slip fixes wall velocity. Darcy–Weisbach uses *section-average* velocity, not centreline speed.

Positive loss must increase with length and speed.

PROFILE, REGIME AND CHART LOGIC

FEATURE	LAMINAR	TURBULENT
Profile	Parabolic in developed circular pipe	Fuller core; steep near-wall gradient
Momentum transport	Molecular viscosity	Mixing plus viscosity
Resistance input	Re alone; f=64/Re	Re and ε/D
Roughness	Not a Moody turbulent curve	May control fully rough limit
Entrance	Do not assume developed profile if pipe is too short	

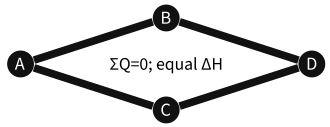
UNKNOWN-FLOW ITERATION

1. Guess Darcy f and solve the energy/loss equation for V or Q.
2. Recompute Re and ε/D, then read or correlate a revised f.
3. Repeat until Q, Re and f are mutually consistent.
4. Close with positive h_L and a regime statement; use operating-temperature properties.

08 Pipe systems + torque C8

ONE CONSTANT-DIAMETER PATH

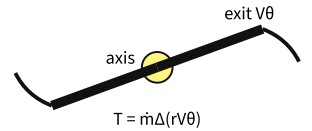
$h_L = (fL/D + \sum K)V^2/(2g)$



Parallel branches share end nodes and head difference, not generally flow rate.

SYSTEM	CONSTRAINT	TRAP
Series	Same Q; add losses	Omitting local K
Parallel	Same node-to-node ΔH	Forcing equal Q
Changing D	Each term uses its named section V	One velocity for all K
Network	Node continuity + independent paths	Lose sign of branch Q
Pump/system	Operating point is curve intersection	Fixed Q assumed

Negative branch Q means flow opposes the assumed arrow; reverse its interpretation and loss direction.



$T = \dot{m}\Delta(rV\theta)$

Only tangential velocity carried at a radius contributes directly to angular momentum about the axis.

TORQUE PROCEDURE

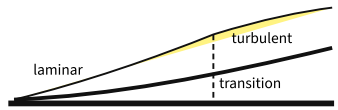
Choose axis/sign → resolve V_θ → sum $\dot{m}rV_\theta$ out minus in → include external moments → reverse only for hardware torque.

09 Boundary layers + drag C9

FORCE AND POWER

$D = \tfrac{1}{2}\rho V^2 C_D A \quad P = DV$

If C_D fixed: $D \propto V^2$; $P \propto V^3$



distance from leading edge

No slip creates the layer; an adverse pressure gradient can drive wall shear to zero and separation.

DRAG COMPONENT	MECHANISM / READING
Skin friction	Wall shear over wetted area
Form drag	Pressure imbalance and wake
C_D use	Carry Re, shape, surface, A convention
Turbulence	Higher skin friction; may delay separation

ENGG2500 Worked drills, traps and fast recall

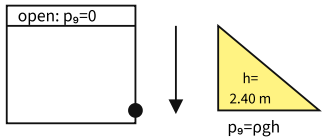
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Full guide + ask Sia about ENGG2500

SIDE 2 · DRILLS — **Five worked chains** · numbers carried to the answer — **KEEP UNITS + SIGN + REGIME VISIBLE**

10 Worked · pressure below surface C1 WEX

Given: tap 2.40 m below an open water surface; ρ=998 kg/m³; g=9.81 m/s²; atmosphere=101 kPa. Find gauge and absolute pressure.



Set the pressure reference before walking down the water column.

1 REFERENCE + STATIC RELATION

$p_{g,surface}=0$

$p_{g,tap}=\rho g h$

2 SUBSTITUTE IN SI

$p_g=998\times9.81\times2.40$

$=23{,}496.9$ Pa = 23.5 kPa gauge

3 CONVERT REFERENCE

$p_{abs}=p_g+p_{atm}$

$=23.5+101=$ 124.5 kPa absolute

CHECK	PASS CONDITION
Direction	Pressure rises with depth
Units	ρgh → kg·m⁻¹·s⁻² = Pa
Reference	Gauge and absolute named

TRAP *Do not add atmosphere when the question asks for gauge pressure; do not compare gauge pressure with vapour pressure.*

Fast hydrostatic recall C1–C2

PROMPT	RESPONSE
Compound manometer	One signed vertical path; swap ρ only at interface
Gate opens?	$F_R=p_cA$; place at centre of pressure; moments
Floating?	$F_B=\rho g V_{disp}$; compare W and restraints
Accelerating tank	Draw effective g; free surface perpendicular

PRESSURE-PATH DIAGNOSTIC

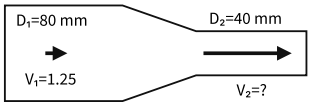
OBSERVATION	INTERPRETATION / REPAIR
Deeper point has lower p	Vertical sign reversed
Horizontal distance appears	Remove it; only elevation changes enter
Interface pressure jumps	p is continuous; gradient changes with ρ
Closed path misses starting p	Segment, density or sign missing
Vapour check uses gauge p	Convert to absolute

RESULTANT-FORCE AUDIT

1. Find A and centroid depth; evaluate p_cA.
2. Locate centre of pressure separately; place F_R on the free-body diagram.

11 Worked · reducer flow C3 WEX

Given: water, D_1=80 mm, D_2=40 mm, V_1=1.25 m/s, ρ=998 kg/m³. Find V_2 and mass flow.



Steady incompressible flow: the fourfold area reduction gives a fourfold speed increase.

1 AREAS

$A_1=\pi(0.080)^2/4=0.005027$ m²

$A_2=\pi(0.040)^2/4=0.001257$ m²

2 CONTINUITY

$A_1V_1=A_2V_2$

$V_2=(A_1/A_2)V_1=4\times1.25=$ 5.00 m/s

3 FLOW RATES

$Q=A_1V_1=0.005027\times1.25$

$=0.006283$ m³/s

$\dot m=\rho Q=998\times0.006283=$ 6.27 kg/s

CHECK	REASON
Diameter halved	Area quartered, not halved
Smaller area	Higher speed for same incompressible Q
Continuity gives	Flux, not pressure

TRAP *Convert diameters to metres and square them before forming area; distinguish Q [m³/s] from ṁ [kg/s].*

Field + branch checks C3

STATEMENT	MEANING
Steady	Local acceleration zero; convective may remain
Streamtube side	V tangent; zero normal flux
Negative branch Q	Actual flow opposite assumed arrow
Filling tank	Positive accumulation even if ρ constant

FULL CONTINUITY BEFORE SHORTCUTS

CONTROL-VOLUME STATEMENT

Accumulation + net outward mass flux = 0

Outflow: $+\rho V_nA$ Inflow: $-\rho V_nA$

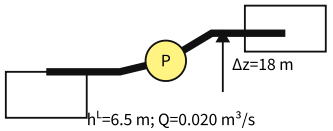
GEOMETRY / FLOW	WHAT SURVIVES
One inlet, one outlet; steady; constant ρ	$A_1V_1=A_2V_2$
Several openings; steady; constant ρ	$\Sigma Q_{in}=\Sigma Q_{out}$
Filling/draining storage	Retain accumulation
Compressible or varying density	Keep ρ with each mass flux
Nonuniform section profile	Use integrated flux or flux-preserving $\bar V$

VISUALISATION TERMS

LINE	DEFINITION
Streamline	Tangent to instantaneous velocity field
Pathline	Trajectory of one particle through time

12 Worked · pumping reservoirs C4 WEX

Given: two open reservoirs; elevation rise 18 m; total h_L=6.5 m at Q=0.020 m³/s; water ρ=998 kg/m³. Find pump head and hydraulic power.



Reservoir surfaces remove gauge-pressure and surface-speed terms for physical reasons.

1 CHOOSE ENDPOINTS

Open surfaces: $p_1=p_2=0$ gauge.

Large reservoirs: $V_1\approx V_2\approx0$. Keep Δz, h_p, h_L.

2 ENERGY EQUATION

$z_1+h_p-h_L=z_2$

$h_p=(z_2-z_1)+h_L$

$=18+6.5=$ 24.5 m

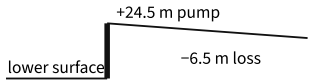
3 HYDRAULIC POWER

$P_{hyd}=\rho g Q h_p$

$=998\times9.81\times0.020\times24.5$

$=4798$ W ≈ 4.80 kW

WHAT IS ASKED?	EFFICIENCY READING
Power delivered to water	$\rho g Q h_p$
Pump shaft input	Greater than hydraulic power if η<1
Turbine shaft output	Less than hydraulic power removed if η<1



The head ledger must close: pump rise minus loss equals reservoir elevation rise.

TRAP *Do not apply pump efficiency unless shaft power is requested; h_L is positive dissipation.*

ENDPOINT SELECTION CATALOGUE

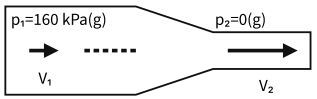
SECTION	KNOWN HEAD TERMS	KEEP
Open reservoir	$p_g=0$; V≈0	z
Free jet	$p_g=0$	$V^2/(2g)$, z
Pipe tap	Area gives V from Q	$p/(\rho g)$, $V^2/(2g)$, z
Pump / turbine	Head exchanged	$+h_p$ / $-h_t$
Passive path	Dissipation	$-h_L$

GRADE-LINE DIAGNOSIS

OBSERVED FEATURE	PHYSICAL READING
EGL – HGL	Velocity head $V^2/(2g)$
Both lines jump upward	Pump adds mechanical energy

13 Worked · nozzle force C5 WEX

Given: water Q=0.030 m³/s enters a 90 mm nozzle at 160 kPa gauge and exits at 45 mm to atmosphere. Neglect weight and losses. Find axial nozzle-on-fluid force.



Pressure force points into the control volume; the wall-force direction is solved, not guessed.

1 CONTINUITY

$A_1=\pi(0.090)^2/4$; $A_2=\pi(0.045)^2/4$

$V_1=Q/A_1=$ 4.72 m/s

$V_2=Q/A_2=$ 18.86 m/s

2 MASS + MOMENTUM CHANGE

$\dot m=$ 30.0 kg/s

$\dot m(V_2-V_1)=30.0(18.86-4.72)=$ 424 N downstream

3 FORCE LEDGER, +X DOWNSTREAM

$p_1A_1=160{,}000\cdot\pi(0.090)^2/4=$ 1018 N downstream

$p_1A_1+F_{wall}=424$

$F_{wall}=424-1018=$ -594 N

Answer: nozzle-on-fluid force = 594 N upstream. By action–reaction, fluid-on-nozzle force = 594 N downstream.

TRAP	CORRECTION
Use speed difference only	Momentum is a vector
Add atmospheric outlet force	Gauge outlet pressure is zero
Report wrong body	Circle "on fluid" or "on nozzle"
Pressure follows flow	Pressure acts inward on the cut

LIMIT CHECK *If there were no pressure thrust, a downstream momentum increase would require a downstream wall force on the fluid.*

Momentum extensions C5

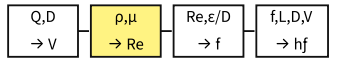
CASE	ADD
Vertical device	Fluid weight if material
Moving vane	Relative incident mass rate; fixed-frame outlet V
Turning bend	x and y component equations
Free jet	Zero gauge pressure at ambient discharge

CONTROL-VOLUME FORCE LEDGER

1. Draw fluid CV; declare axes and reference frame.
2. Use continuity for ṁ and section velocities; use energy only for a missing speed.
3. Draw pressure inward, add material fluid weight, and label wall/support *force on fluid*.
4. Write outlet minus inlet momentum flux by component.

14 Worked · major pipe loss C7 WEX

Given: water Q=0.40 L/s through L=12 m of D=25 mm pipe; ρ=998 kg/m³; μ=0.001 Pa·s; Darcy f=0.032. Find V, Re and h_f.



classify before selecting resistance

Keep the friction-factor convention visible through the entire calculation.

1 CONVERT + VELOCITY

$Q=0.00040$ m³/s; $D=0.025$ m

$A=\pi D^2/4=0.0004909$ m²

$V=Q/A=$ 0.815 m/s

2 REYNOLDS NUMBER

$Re=\rho VD/\mu$

$=998\times0.815\times0.025/0.001$

$\approx$ 20,300 → turbulent

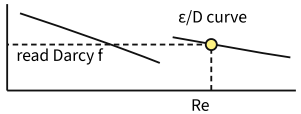
3 DARCY–WEISBACH

$h_f=f(L/D)V^2/(2g)$

$=0.032(12/0.025)(0.815^2/(2\times9.81))$

$=$ 0.520 m

SENSITIVITY	READING
Longer L	Higher h_f
Larger V	Higher h_f through V^2 and possible f shift
Larger D at fixed Q	Lower V and L/D; strong loss reduction
Higher temperature	Property change shifts Re and possibly f



Turbulent chart path: Re across, intersect ε/D curve, then read Darcy f.

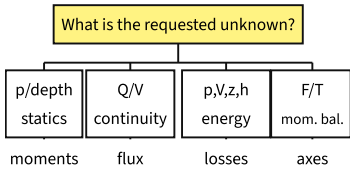
TRAP *The given 0.032 is Darcy. Substituting a Fanning factor in Darcy–Weisbach makes the loss four times too small.*

SYSTEM-LOSS RECALL

ELEMENT	LOSS HANDLING
Straight constant-D pipe	$f(L/D)V^2/(2g)$
Entrance, exit, valve, bend	$KV^2/(2g)$, with coefficient's stated section V
One constant-D series path	$(fL/D+\Sigma K)V^2/(2g)$
Changing diameters	Compute each loss with its own section velocity
Parallel branches	Equal end-to-end head difference; Q divides
Whole network	Independent node and path equations; one reference head

SIMILARITY + DRAG FAST RECALL

15 Method chooser under time pressure C1–C9



Combine balances as needed

Choose the law from the unknown and mechanism—not from whichever formula looks familiar.

IF THE STEM GIVES…	IMMEDIATE SETUP
Static levels, densities	Known p → signed manometer walk
Area change, steady liquid	Q=AV at each section
Reservoirs, pump, losses	General energy at simple endpoints
Nozzle/bend/support force	Continuity → energy if needed → vector momentum
Model scale	Rank → n−r Π groups → match dominant group
Pipe Q, D, roughness	V → Re → ε/D → Darcy f → h_L
External drag	Re + area convention + valid C_D

16 High-cost traps C1–C9

WRONG MOVE	REPAIR
Mix gauge and absolute p	Name reference
Centroid as force location	Find centre of pressure
Cancel ρ without constant-density condition	Write full mass balance
Bernoulli through pump/loss	Use general energy equation
Scalar V in a bend	Resolve vector components
Mix Darcy and Fanning f	Label factor convention
Copy C_D alone	Carry Re, shape, surface, A

FINAL LINE *State a direction, regime or physical plausibility conclusion–not only a number.*

17 One-line formula index C1–C9

Statics	$\Delta p=\rho g\Delta h$; $F_R=p_cA$; $F_B=\rho g V_{disp}$
Flux	$Q=\bar VA$; $\dot m=\rho Q$
Energy	$p/\rho g+V^2/2g+z$; $+h_p-h_t-h_L$
Momentum	$\sum F=\dot m(V_{out}-V_{in})$
Similarity	$\pi-r$; $Re=\rho VL/\mu$
Pipe	$h_L=(fL/D+\sum K)V^2/2g$
Drag	$D=\frac12\rho V^2C_DA$; $P=DV$

LAST 90-SECOND AUDIT

LOOK FOR	QUESTION TO ASK
Geometry	Are diameter, area, datum, axes and control boundary labelled?
Assumptions	Did each cancelled term get a physical reason?