997

Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

Semester II Examinations, 2004/2005

Exam Code(s)	2BM121, 2BG121
Exam(s)	2nd Year Engineering (Mechanical, Biomedical)
Module Code(s)	ME207
Module(s)	Introduction to Fluid Mechanics
Paper No.	-
Repeat Paper	- Special Paper -
External Examiner(s)	Professor J. Fitzpatrick
Internal Examiner(s)	Professor J.F. McNamara
	Dr. J.A. Eaton

Instructions:

- Answer 3 questions.
- All questions will be marked equally.
- For every question attempted, produce at least one sketch or diagram that is clearly and accurately labelled with symbols and appropriate dimensions. State the assumptions your analyses are based upon, and show all your workings.
- Attached are the following information:
  - — Equations Sheet
  - — Physical Properties Tables
  - — Properties of Plane Areas

Duration	2 hrs
No. of Answer books	1 -

Requirements:

Handout	-
MCQ	-
Statistical Tables	Yes Log Tables
Graph Paper	-
Log Graph Paper	-
Other Material	-

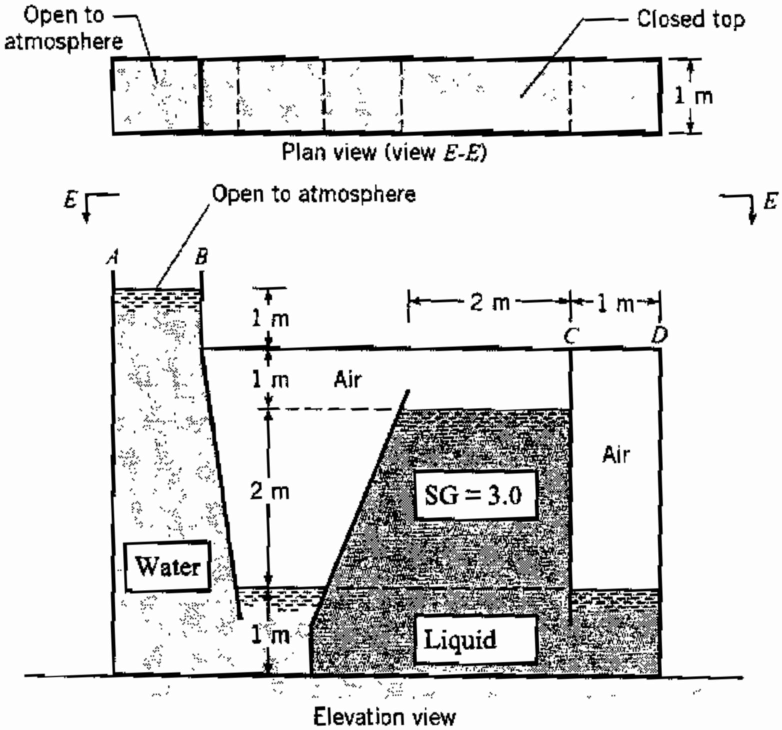
No. of Pages	7
Department(s)	Mechanical and Biomedical Engineering

1. For the tank shown in ***Figure 1***, assuming $T = 20° C$:

   (a) What is the maximum gauge pressure in the tank, and where will this maximum pressure occur?

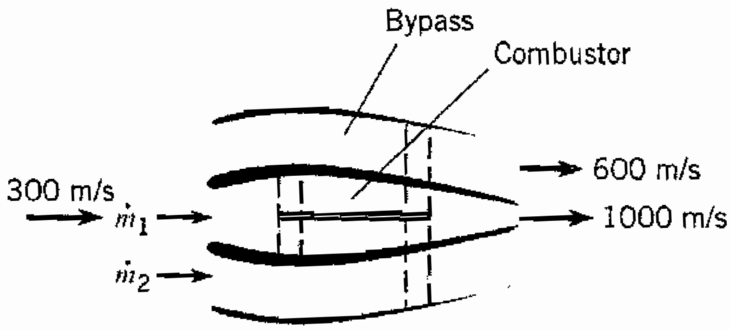
   (b) What is the hydrostatic force acting on the top (CD) of the last chamber on the right-hand side of the tank? (20 points)

Figure 1



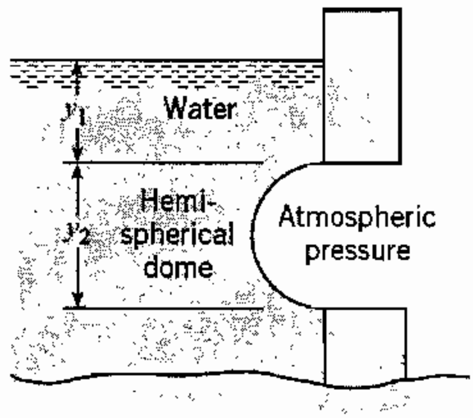
2. As shown in ***Figure 2***, a turbofan engine for a jet aircraft takes in air, part of which passes through the compressor, combustion chamber and turbine (the *core flow*); the remainder of the air bypasses the compressor and is accelerated by the fan blades (the *bypass flow*). The ratio of mass flow rate of the bypass air to the mass flow rate through the core path is called the bypass ratio. During flight the total flow rate of air entering such a turbofan is 300 kg/s with a velocity of 300 m/s, and the engine has a bypass ratio of 2.5. The bypass air exits at 600 m/s, whereas the core flow air exits at 1000 m/s. What is the thrust of the turbofan engine? (20 points)

Figure 2



3. A viewing dome (hemisphere) is located below the water surface as shown in ***Figure 3***. Determine the magnitude and direction of the force components needed to hold the dome in place and the line of action of the horizontal component of the force. Dimensions $y_1 = 1$ m, $y_2 = 2$ m, and $T = 20°$ C. (20 points)

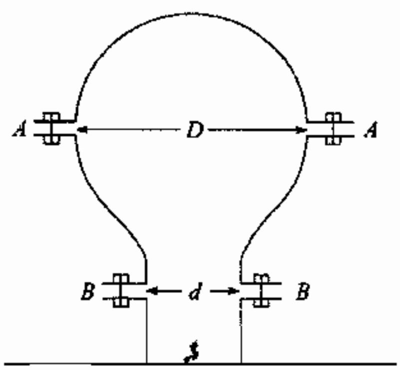
Figure 3



4. (a) If exactly 20 bolts of 25-mm-diameter are needed to hold the air pressure vessel shown in ***Figure 4a*** together at A – A as a result of the high pressure within, how many of the same bolt type will be needed at B – B? Diameter D = 40 cm, diameter d = 20 cm. (10 points)

(b) A drop of water at 20° C is forming on a surface. The configuration just before separating and falling as a drop is shown in ***Figure 4b.*** Assuming the forming drop has the volume and shape of a hemisphere, what will be its diameter before separating? (10 points)

Figure 4a



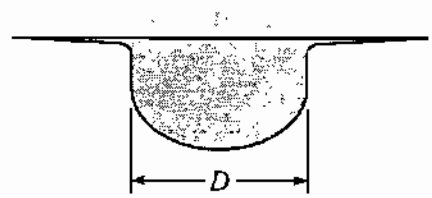
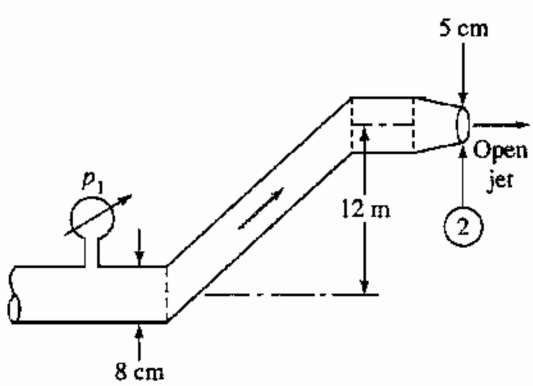


Figure 4b

5. In ***Figure 5*** the fluid is gasoline at 20° C flowing at a weight flux of 120 N/s. Assuming no losses, calculate the gauge pressure at Section 1. (20 points)

Figure 5



EQUATION SHEET

Ideal-gas law: $p = \rho RT$, $R_{air} = 287$ J/kg-K	Surface tension: $\Delta p = Y(R_1^{-1} + R_2^{-1})$
Hydrostatics, constant density: $p_2 - p_1 = -\gamma(z_2 - z_1)$, $\gamma = \rho g$	Hydrostatic panel force: $F = \gamma h_{CG} A$, $y_{CP} = -I_{xx}\sin\theta/(h_{CG}A)$, $x_{CP} = -I_{xy}\sin\theta/(h_{CG}A)$
Buoyant force: $F_B = \gamma_{fluid}$(displaced volume)	CV mass: $d/dt(\int_{cv} \rho\, d\upsilon) + \Sigma(\rho AV)_{out}$ $- \Sigma(\rho AV)_{in} = 0$
CV momentum: $d/dt\,(\int_{cv} \rho V d\upsilon)$ $+ \Sigma[(\rho AV)V]_{out} - \Sigma[(\rho AV)V]_{in} = \Sigma F$	CV angular momentum: $d/dt(\int_{cv} \rho(r_0 \times V) d\upsilon)$ $+ \Sigma\rho AV(r_0 \times V)_{out} - \Sigma\rho AV(r_0 \times V)_{in} = \Sigma M_0$
Steady flow energy: $(p/\gamma + \alpha V^2/2g + z)_{in} =$ $(p/\gamma + \alpha V^2/2g + z)_{out} + h_{friction} - h_{pump} + h_{turbine}$	Acceleration: $dV/dt = \partial V/\partial t$ $+ u(\partial V/\partial x) + v(\partial V/\partial y) + w(\partial V/\partial z)$
Incompressible continuity: $\nabla \cdot V = 0$	Navier-Stokes: $\rho(dV/dt) = \rho g - \nabla p + \mu \nabla^2 V$
Incompressible stream function $\psi(x,y)$: $u = \partial\psi/\partial y$; $v = -\partial\psi/\partial x$	Velocity potential $\phi(x,y,z)$: $u = \partial\phi/\partial x$; $v = \partial\phi/\partial y$; $w = \partial\phi/\partial z$
Bernoulli unsteady irrotational flow: $\partial\phi/\partial t + \int dp/\rho + V^2/2 + gz = Const$	Turbulent friction factor: $1/\sqrt{f} =$ $-2.0\, log_{10}[\varepsilon/(3.7d) + 2.51/(Re_d \sqrt{f})]$
Pipe head loss: $h_f = f(L/d)V^2/(2g)$ where f = Moody-chart friction factor	Orifice, nozzle, venturi flow: $Q = C_d A_{throat}[2\Delta p/\{\rho(1-\beta^4)\}]^{1/2}$, $\beta = d/D$
Laminar flat plate flow: $\delta/x = 5.0/Re_x^{1/2}$, $c_f = 0.664/Re_x^{1/2}$, $C_D = 1.328/Re_L^{1/2}$	Turbulent flat plate flow: $\delta/x = 0.16/Re_x^{1/7}$, $c_f = 0.027/Re_x^{1/7}$, $C_D = 0.031/Re_L^{1/7}$
$C_D = Drag/(\frac{1}{2}\rho V^2 A)$; $C_L = Lift/(\frac{1}{2}\rho V^2 A)$	2-D Potential flow: $\nabla^2\phi = \nabla^2\psi = 0$
Isentropic flow: $T_o/T = 1 + \{(k-1)/2\}Ma^2$, $\rho_o/\rho = (T_o/T)^{1/(k-1)}$, $p_o/p = (T_o/T)^{k/(k-1)}$	One-dimensional isentropic area change: $A/A^* = (1/Ma)[1 + \{(k-1)/2\}Ma^2]^{(1/2)(k+1)/(k-1)}$
Prandtl-Meyer expansion: $K = (k+1)/(k-1)$, $\Omega = K^{1/2} \tan^{-1}[(Ma^2-1)/K]^{1/2} - \tan^{-1}(Ma^2-1)^{1/2}$	Uniform flow, Manning's n, SI units: $V_o(m/s) = (1.0/n)[R_h(m)]^{2/3} S_o^{1/2}$
Gradually-varied channel flow: $dy/dx = (S_o - S)/(1 - Fr^2)$, $Fr = V/V_{crit}$	Euler turbine formula: $Power = \rho Q(u_2 V_{t2} - u_1 V_{t1})$, $u = r\omega$

Table A.3 Properties of Common Liquids at 1 atm and 20°C (68°F)

Liquid	ρ, kg/m³	μ, kg/(m · s)	Y, N/m*	p_v, N/m²	Bulk modulus, N/m²	Viscosity parameter C†
Ammonia	608	2.20 E-4	2.13 E-2	9.10 E+5	—	1.05
Benzene	881	6.51 E-4	2.88 E-2	1.01 E+4	1.4 E+9	4.34
Carbon tetrachloride	1,590	9.67 E-4	2.70 E-2	1.20 E+4	9.65 E+8	4.45
Ethanol	789	1.20 E-3	2.28 E-2	5.7 E+3	9.0 E+8	5.72
Ethylene glycol	1,117	2.14 E-2	4.84 E-2	1.2 E+1	—	11.7
Freon 12	1,327	2.62 E-4	—	—	—	1.76
Gasoline	680	2.92 E-4	2.16 E-2	5.51 E+4	9.58 E+8	3.68
Glycerin	1,260	1.49	6.33 E-2	1.4 E-2	4.34 E+9	28.0
Kerosine	804	1.92 E-3	2.8 E-2	3.11 E+3	1.6 E+9	5.56
Mercury	13,550	1.56 E-3	4.84 E-1	1.1 E-3	2.55 E+10	1.07
Methanol	791	5.98 E-4	2.25 E-2	1.34 E+4	8.3 E+8	4.63
SAE 10W oil	870	1.04 E-1‡	3.6 E-2	—	1.31 E+9	15.7
SAE 10W30 oil	876	1.7 E-1‡	—	—	—	14.0
SAE 30W oil	891	2.9 E-1‡	3.5 E-2	—	1.38 E+9	18.3
SAE 50W oil	902	8.6 E-1‡	—	—	—	20.2
Water	998	1.00 E-3	7.28 E-2	2.34 E+3	2.19 E+9	Table A.1
Seawater (30%)	1,025	1.07 E-3	7.28 E-2	2.34 E+3	2.33 E+9	7.28

*In contact with air.

†The viscosity-temperature variation of these liquids may be fitted to the empirical expression

$$\frac{\mu}{\mu_{20^\circ C}} \approx \exp\left[C\left(\frac{293\ \text{K}}{T\ \text{K}} - 1\right)\right]$$

with accuracy of ±6 percent in the range $0 \le T \le 100$°C.

‡Representative values. The SAE oil classifications allow a viscosity variation of up to ±50 percent, especially at lower temperatures.

Table A.4 Properties of Common Gases at 1 atm and 20°C (68°F)

Gas	Molecular weight	R, m²/(s² · K)	ρg, N/m³	μ, N · s/m²	Specific-heat ratio	Power-law exponent n†
H_2	2.016	4124	0.822	9.05 E-6	1.41	0.68
He	4.003	2077	1.63	1.97 E-5	1.66	0.67
H_2O	18.02	461	7.35	1.02 E-5	1.33	1.15
Ar	39.944	208	16.3	2.24 E-5	1.67	0.72
Dry air	28.96	287	11.8	1.80 E-5	1.40	0.67
CO_2	44.01	189	17.9	1.48 E-5	1.30	0.79
CO	28.01	297	11.4	1.82 E-5	1.40	0.71
N_2	28.02	297	11.4	1.76 E-5	1.40	0.67
O_2	32.00	260	13.1	2.00 E-5	1.40	0.69
NO	30.01	277	12.1	1.90 E-5	1.40	0.78
N_2O	44.02	189	17.9	1.45 E-5	1.31	0.89
Cl_2	70.91	117	28.9	1.03 E-5	1.34	1.00
CH_4	16.04	518	6.54	1.34 E-5	1.32	0.87

†The power-law curve fit, Eq. (1.27), $\mu/\mu_{293K} \approx (T/293)^n$, fits these gases to within ±4 percent in the range $250 \le T \le 1000$ K. The temperature must be in kelvins.

Table A.5 Surface Tension, Vapor Pressure, and Sound Speed of Water

T, °C	Υ, N/m	p_v, kPa	a, m/s
0	0.0756	0.611	1402
10	0.0742	1.227	1447
20	0.0728	2.337	1482
30	0.0712	4.242	1509
40	0.0696	7.375	1529
50	0.0679	12.34	1542
60	0.0662	19.92	1551
70	0.0644	31.16	1553
80	0.0626	47.35	1554
90	0.0608	70.11	1550
100	0.0589	101.3	1543
120	0.0550	198.5	1518
140	0.0509	361.3	1483
160	0.0466	617.8	1440
180	0.0422	1,002	1389
200	0.0377	1,554	1334
220	0.0331	2,318	1268
240	0.0284	3,344	1192
260	0.0237	4,688	1110
280	0.0190	6,412	1022
300	0.0144	8,581	920
320	0.0099	11,274	800
340	0.0056	14,586	630
360	0.0019	18,651	370
374*	0.0*	22,090*	0*

*Critical point.

Table A.6 Properties of the Standard Atmosphere

z, m	T, K	p, Pa	ρ, kg/m^3	a, m/s
−500	291.41	107,508	1.2854	342.2
0	288.16	101,350	1.2255	340.3
500	284.91	95,480	1.1677	338.4
1,000	281.66	89,889	1.1120	336.5
1,500	278.41	84,565	1.0583	334.5
2,000	275.16	79,500	1.0067	332.6
2,500	271.91	74,684	0.9570	330.6
3,000	268.66	70,107	0.9092	328.6
3,500	265.41	65,759	0.8633	326.6
4,000	262.16	61,633	0.8191	324.6
4,500	258.91	57,718	0.7768	322.6
5,000	255.66	54,008	0.7361	320.6
5,500	252.41	50,493	0.6970	318.5
6,000	249.16	47,166	0.6596	316.5
6,500	245.91	44,018	0.6237	314.4
7,000	242.66	41,043	0.5893	312.3
7,500	239.41	38,233	0.5564	310.2
8,000	236.16	35,581	0.5250	308.1
8,500	232.91	33,080	0.4949	306.0
9,000	229.66	30,723	0.4661	303.8
9,500	226.41	28,504	0.4387	301.7
10,000	223.16	26,416	0.4125	299.5
10,500	219.91	24,455	0.3875	297.3
11,000	216.66	22,612	0.3637	295.1
11,500	216.66	20,897	0.3361	295.1
12,000	216.66	19,312	0.3106	295.1
12,500	216.66	17,847	0.2870	295.1
13,000	216.66	16,494	0.2652	295.1
13,500	216.66	15,243	0.2451	295.1
14,000	216.66	14,087	0.2265	295.1
14,500	216.66	13,018	0.2094	295.1
15,000	216.66	12,031	0.1935	295.1
15,500	216.66	11,118	0.1788	295.1
16,000	216.66	10,275	0.1652	295.1
16,500	216.66	9,496	0.1527	295.1
17,000	216.66	8,775	0.1411	295.1
17,500	216.66	8,110	0.1304	295.1
18,000	216.66	7,495	0.1205	295.1
18,500	216.66	6,926	0.1114	295.1
19,000	216.66	6,401	0.1029	295.1
19,500	216.66	5,915	0.0951	295.1
20,000	216.66	5,467	0.0879	295.1
22,000	218.6	4,048	0.0645	296.4
24,000	220.6	2,972	0.0469	297.8
26,000	222.5	2,189	0.0343	299.1
28,000	224.5	1,616	0.0251	300.4
30,000	226.5	1,197	0.0184	301.7
40,000	250.4	287	0.0040	317.2
50,000	270.7	80	0.0010	329.9
60,000	255.7	22	0.0003	320.6
70,000	219.7	6	0.0001	297.2

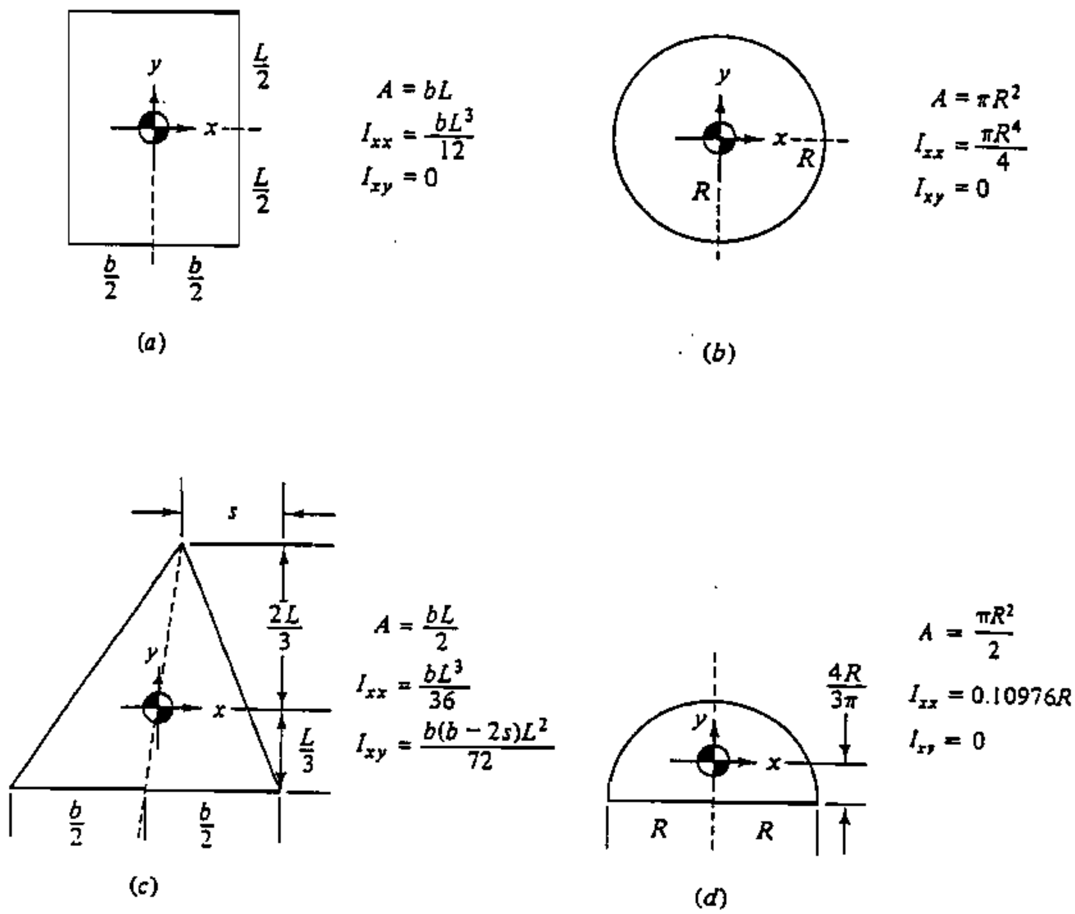


Fig. 2.13 Centroidal moments of inertia for various cross sections: (*a*) rectangle, (*b*) circle, (*c*) triangle, and (*d*) semicircle.