CHARLES DARWIN UNIVERSITY

Family Name	
Given Names	
Student Number	
Teaching Period	Semester 1, 2017

FINAL EXAMINATION	**DURATION**
ENG247 – Fluid and Thermodynamics	Reading Time: **10** minutes Writing Time: **180** minutes

INSTRUCTIONS TO CANDIDATES

1. Read all questions carefully.
2. Answer all questions.
3. Exam is worth 50% of total marks for this unit.
4. Total marks available for this test is 100.
5. Questions are not of equal value.

EXAM CONDITIONS

You may begin writing from the commencement of the examination session. The reading time indicated above is provided as a guide only.

This is a RESTRICTED OPEN BOOK examination

Any calculator is permitted

No handwritten notes are permitted

Hard copy, unannotated English translation dictionary only

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
No additional printed material is permitted	1 x 20 Page Book

THIS EXAMINATION IS PRINTED DOUBLE-SIDED.

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Answered ALL questions in the Answer Booklet provided.

Marks for each question are indicated.

Question 1

With the aid of a diagram, explain the difference between Newtonian and non-Newtonian fluids. Give examples of Newtonian and non-Newtonian fluids.

(Marks: 5)

Question 2

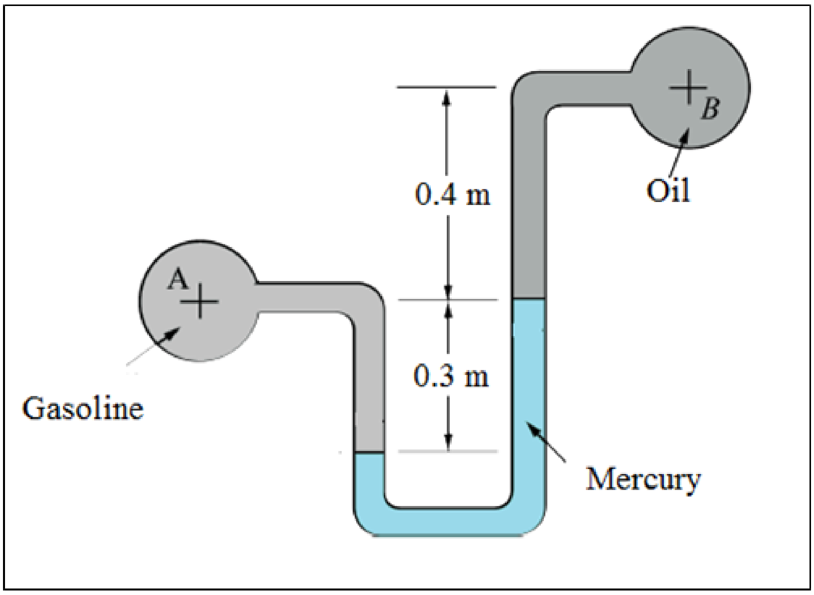
A fire hose nozzle has a diameter of 3 cm. According to the fire codes, the nozzle must be capable of delivering at least 16 l/s. If the nozzle is attached to an 8 cm diameter hose, what pressure must be maintained upstream of the nozzle to deliver this flowrate?

(Marks: 10)

Question 3

In the figure below, a pipe *A* contains gasoline (*SG* = 0.7), pipe *B* contains oil (*SG* = 0.9), and the manometer fluid is mercury. Determine the new differential reading if the pressure in pipe *A* is decreased 25 kPa, and the pressure in pipe *B* remains constant. The initial differential reading is 0.3 m as shown.

(Marks: 10)



(Fundamentals of Fluid Mechanics Munson, Young, Okiishi and Huebsch Wiley 2013, 7th Edition)

Question 4

(a) Explain why the viscosity of gases increases with an increase in temperature whereas viscosity of liquids decreases with an increase in temperature.

(Marks: 5)

(b) State the *Kelvin–Planck* statement of the second law of thermodynamics.

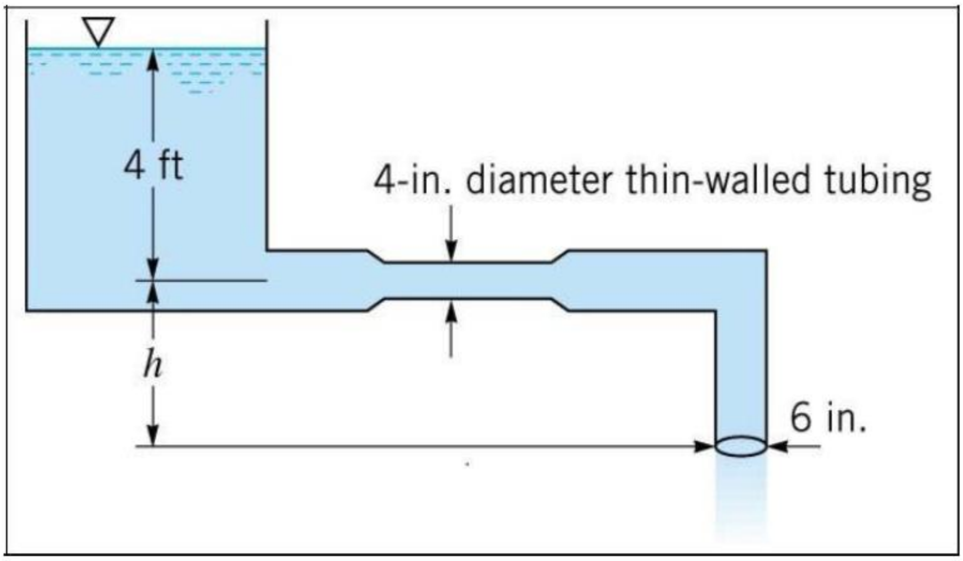
(Marks: 5)

(c) Describe the working principle of a hydraulic press.

(Marks: 5)

Question 5

The diagram below shows salt-water being forced out of a tank. The distance between the outlet and the base of the tank is 1.00 ft.



(a) What is the fluid velocity of the water leaving the tube?

(Marks: 5)

(b) Determine the water pressure in the tubing where the diameter is 4-in?

(Marks: 5)

(c) Given the water is at a temperature of 20 °C, determine the value of h that would result in cavitation occurring in the 4-in narrowing of the tube, if the vapour pressure is 2340 Pa?

(Marks: 10)

Question 6

The volume of 1.0 kg of helium in a piston-cylinder device is initially 5.0 m^3. The cylinder is compressed to 3.0 m^3 with the pressure remaining constant at 200 kPa. Determine the initial and final temperature of the helium gas as well as the work required to compress the gas.

(Marks: 10)

Question 7

The inner and outer surfaces of a 0.50 cm thick 2.0 m × 2.0 m glass window pane are 10 ^oC and 3 ^oC respectively. Determine:

(a) The heat loss, in kJ over a period of 5.0 hours if the thermal conductivity of glass is 0.78 W/(m·^oC).

(Marks: 5)

(b) The heat loss if the glass were 1.0 cm thick.

(Marks: 5)

Question 8

The specific heat of superheated steam at approximately 150 kPa can be determined by the equation

$$C_p = 2.07 + \frac{T - 400}{1480} \text{ kJ/kg·°C}$$

(a) What is the enthalpy change between 300 °C and 700 °C for 3 kg of steam?

(Marks: 10)

(b) What is the average value of C_p between 300 °C and 700 °C ?

(Marks: 10)

THE END

ENG247 - Formula set

Hydrostatics

$v = 1/\rho$ $\qquad \gamma = \rho g$ $\qquad SG = \rho/\rho_{H_2O}$

$pV = nRT$ $\qquad p = \rho R^* T$

$\dot{\gamma} = \frac{U}{b} = \frac{du}{dy}$ $\qquad \tau = \mu \frac{du}{dy}$ $\qquad \nu = \frac{\mu}{\rho}$

$\Delta p = \frac{2\sigma}{R}$ $\qquad h = \frac{2\sigma \cos(\theta)}{\rho g R}$

$\frac{\partial p}{\partial x} = 0$ $\qquad \frac{\partial p}{\partial z} = -\gamma = -\rho g$ $\qquad p = p_a + \gamma h$

$F_R = \gamma A y_c \sin\theta = \gamma h_c A$ $\qquad y_R = \frac{I_{xc}}{A y_c} + y_c$

$F_b = \gamma V$

Hydrodynamics

$a_s = v\frac{\partial v}{\partial s}$ $\qquad a_n = v^2/R$

$\int \frac{dp}{\rho} + gz + \frac{1}{2}\rho v^2 = C$ $\qquad p + \gamma h + \frac{1}{2}\rho v^2 = C$

$p + \gamma z + \rho \int \frac{v^2}{R} = C$

$\dot{m} = \rho v A = \rho Q$ $\qquad \rho_1 A_1 v_1 = \rho_2 A_2 v_2$

$Q = vA$ $\qquad v_1 A_1 = v_2 A_2$ $\qquad Q = A_2\sqrt{\frac{2(p_2 - p_1)}{\rho(1 - A_2^2/A_1^2)}}$

$$\begin{aligned}
\frac{D()}{Dt} &= \frac{\partial()}{\partial t} + u\frac{\partial()}{\partial x} + v\frac{\partial()}{\partial y} + w\frac{\partial()}{\partial z} \\
\mathbf{a} &= \frac{D\mathbf{v}}{Dt} = \frac{\partial \mathbf{v}}{\partial t} + u\frac{\partial \mathbf{v}}{\partial x} + v\frac{\partial \mathbf{v}}{\partial y} + w\frac{\partial \mathbf{v}}{\partial z} \\
\mathbf{a} &= v\frac{\partial v}{\partial s}\hat{\mathbf{s}} + \frac{v^2}{R}\hat{\mathbf{n}} \\
\frac{DB_{sys}}{Dt} &= \frac{\partial}{\partial t}\iiint_{cv} \rho b dV + \oint\oint_{cvs} \rho b \mathbf{v}\cdot\hat{\mathbf{n}} dA \\
0 &= \frac{\partial}{\partial t}\iiint_{cv} \rho dV + \oint\oint_{cvs} \rho \mathbf{v}\cdot\hat{\mathbf{n}} dA \\
\frac{D\mathbf{p}_{sys}}{Dt} &= \frac{\partial}{\partial t}\iiint_{cv} \rho \mathbf{v} dV + \oint\oint_{cvs} \rho \mathbf{v}(\mathbf{v}\cdot\hat{\mathbf{n}}) dA \\
\frac{D\mathbf{p}_{sys}}{Dt} &= \dot{m}\left(\mathbf{v}_{out} - \mathbf{v}_{in}\right)
\end{aligned}$$

Energy Equation

$$\dot{Q}_{in} + \dot{W}_{shaft} = \frac{\partial}{\partial t}\iiint_{cv} e\rho \mathbf{v} dV + \oint\oint_{cvs}\left(u + \frac{p}{\rho} + \frac{v^2}{2} + gz\right)\rho(\mathbf{v}\cdot\hat{\mathbf{n}})dA$$

$\Delta U = \Delta Q + \Delta W$ $\qquad e = u + \frac{v^2}{2} + gz$

$\Delta U = C\Delta T$ $\qquad \Delta u = c\Delta T$ $\qquad h = u + \frac{p}{\rho}$

$u_{out} - u_{in} - q_{in} \geq 0$ $\qquad u_{out} - u_{in} - q_{in} = \text{loss}$ $\qquad \dot{u} = u/\dot{m}$

$h_{in} = w_{in}/g = \dot{W}_{in}/(\dot{m}g) = \dot{W}_{in}/(\gamma Q)$ $\qquad h_L = \text{loss}/g$

Energy equation (Cont)

$$\dot{m}\left[u_{out} - u_{in} + \left(\frac{p}{\rho}\right)_{out} - \left(\frac{p}{\rho}\right)_{in} + \frac{v_{out}^2 - v_{in}^2}{2} + g(z_{out} - z_{in})\right] = \dot{Q}_{in} + \dot{W}_{shaft-in}$$

$$\frac{p_{out}}{\rho} + \frac{v_{out}^2}{2} + gz_{out} = \frac{p_{in}}{\rho} + \frac{v_{in}^2}{2} + gz_{in} + w_{in} - \text{loss}$$

$$\frac{p_{out}}{\gamma} + \frac{v_{out}^2}{2g} + z_{out} = \frac{p_{in}}{\gamma} + \frac{v_{in}^2}{2g} + z_{in} + h_{in} - h_L$$

Pipes

$$h_{L_{major}} = f\frac{l}{D}\frac{v^2}{2g} \quad h_{L_{minor}} = K_L\frac{v^2}{2g} \quad f = \frac{64}{\text{Re}}$$

Dimensionless numbers

$$\text{Re} = \frac{\rho v D}{\mu} \quad \text{Ma} = \frac{v}{c} \quad \text{Fr} = \frac{v^2}{gl}$$

Vector products

$$\mathbf{A}\cdot\mathbf{B} = |\mathbf{A}||\mathbf{B}|\cos\theta \qquad \mathbf{A}\cdot\mathbf{B} = A_xB_x + A_yB_y + A_zB_z$$

$$\mathbf{i}\cdot\mathbf{i} = \mathbf{j}\cdot\mathbf{j} = \mathbf{k}\cdot\mathbf{k} = 1 \qquad \mathbf{i}\cdot\mathbf{j} = \mathbf{j}\cdot\mathbf{i} = \mathbf{j}\cdot\mathbf{k} = \mathbf{k}\cdot\mathbf{j} = \mathbf{i}\cdot\mathbf{k} = \mathbf{k}\cdot\mathbf{i} = 0$$

$$\mathbf{A}\times\mathbf{B} = |\mathbf{A}||\mathbf{B}|\sin\theta$$

$$\mathbf{i}\times\mathbf{j} = \mathbf{k} \quad \mathbf{j}\times\mathbf{i} = -\mathbf{k} \quad \mathbf{j}\times\mathbf{k} = \mathbf{i} \quad \mathbf{k}\times\mathbf{j} = -\mathbf{i} \quad \mathbf{k}\times\mathbf{i} = \mathbf{j} \quad \mathbf{i}\times\mathbf{k} = -\mathbf{j}$$

$$\mathbf{i}\times\mathbf{i} = \mathbf{j}\times\mathbf{j} = \mathbf{k}\times\mathbf{k} = 0$$

Mechanics

$\mathbf{v} = d\mathbf{x}/dt$	$\mathbf{a} = d\mathbf{v}/dt$	$\mathbf{a} = v\,d\mathbf{v}/dx$
$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$		$\mathbf{x} = \mathbf{x}_0 + \mathbf{v}_0 t + (1/2)\mathbf{a}t^2$
$\omega = d\theta/dt = v/r$	$a = v^2/r = \omega^2/r$	$\omega = 2\pi f = 2\pi/T$
$\mathbf{p} = m\mathbf{v}$	$\mathbf{F} = d\mathbf{p}/dt$	$\mathbf{F} = m\mathbf{a}$
$K = \frac{1}{2}mv^2 = p^2/(2m)$	$W = \int \mathbf{F}\cdot d\mathbf{r}$	$\mathbf{L} = \mathbf{r}\times\mathbf{p}$
$\boldsymbol{\tau} = \mathbf{r}\times\mathbf{F} = d\mathbf{L}/dt$	$L = I\omega$	$K = \frac{1}{2}I\omega^2 = L^2/2I$

Thermodynamics

$v = 1/\rho$ $\quad V = mv$

$pv = RT$ $\quad pV = mRT$

$\Delta U = \Delta Q + \Delta W_{in}$ $\quad \Delta u = \Delta q + \Delta w$ $\quad \Delta w_{out} = \int p dv$

$h = u + pv$

$x = \frac{m_g}{m_{\text{total}}}$ $\quad x = \frac{y - y_f}{y_{fg}}$ $\quad y = y_f + x y_{fg}$

$y = \frac{y_2 - y_1}{x_2 - x_1}(x - x_1) + y_1$ $\quad h \approx h_{f@SAT} + v_{SAT}(p - p_{SAT})$

$c_v = \left(\frac{\partial u}{\partial T}\right)_v$ $\quad c_p = \left(\frac{\partial h}{\partial T}\right)_p$ $\quad C_v = mc_v$

$c_p = c_v + R$ $\quad k = \frac{c_p}{c_v}$

$pv^k = C$ $\quad Tv^{k-1} = C'$ $\quad p^{\frac{1-k}{k}} T = C$

$\Delta w = \frac{1}{k-1}[p_1 v_1 - p_2 v_2]$ $\quad \Delta w = \frac{R}{k-1}[T_1 - T_2]$

Energy Equation

$$\begin{aligned} \dot{Q} + \dot{W}_{in} &= \dot{m}(h_2 - h_1) + \dot{m}\frac{v_2^2 - v_1^2}{2} + \dot{m}(gz_2 - gz_1) \\ q + w_{in} &= (h_2 - h_1) + \frac{v_2^2 - v_1^2}{2} + (gz_2 - gz_1) \end{aligned}$$

2nd Law

$W_{out} = Q_H - Q_L$ $\quad \eta = \frac{W_{out}}{Q_H}$ $\quad \eta = 1 - \frac{Q_L}{Q_H}$

$Q_L = Q_H - W_{in}$ $\quad \text{COP}_{\text{ref}} = \frac{Q_L}{W_{in}}$ $\quad \text{COP}_{HP} = \frac{Q_H}{W_{in}}$

$\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$ $\quad \eta_{\text{rev}} = 1 - \frac{T_L}{T_H}$ $\quad \text{COP}_{\text{HP,rev}} = \frac{1}{1 - T_L/T_H}$ $\quad \text{COP}_{\text{ref,rev}} = \frac{1}{T_H/T_L - 1}$

Entropy

$$\Delta S \geq \int \frac{dQ}{T} \qquad Tds = du + pdv \quad Tds = dh - vdp$$

$$\Delta S_{\text{rev}} = \int \frac{dQ}{T} \quad \Delta Q_{\text{rev}} = \int TdS$$

$$s_2 - s_1 = \int_1^2 c_v(T)\frac{dT}{T} + R\ln\left(\frac{v_2}{v_1}\right) \quad s_2 - s_1 = \int_1^2 c_p(T)\frac{dT}{T} - R\ln\left(\frac{p_2}{p_1}\right)$$

$$s_2 - s_1 = \langle c_v \rangle \ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{v_2}{v_1}\right) \quad s_2 - s_1 = \langle c_p \rangle \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{p_2}{p_1}\right)$$

Cycles

$$\eta_{\text{Otto}} = 1 - \frac{1}{r^{k-1}} \qquad r = \frac{V_{BDC}}{V_{TDC}} \quad \eta_{Otto} = 1 - \frac{T_1}{T_2}$$

$$\eta_{\text{Diesel}} = 1 - \frac{1}{kr^{k-1}}\frac{(r_c^k - 1)}{(r_c - 1)}$$

$$\eta_{\text{Brayton}} = 1 - \frac{1}{r_p^{\frac{k-1}{k}}} \qquad r_p = \frac{p_2}{p_1}$$

Constants

$R = 8.3145$ J kg/(mol K)	$T(^oC) = T(K) - 273.15$	$g = 9.80$ ms^{-2}
amu $= 1.6605 \times 10^{-27}$ kg	$k_B = 1.3807 \times 10^{-23}$ J/K	$N_A = 6.002 \times 10^{23}$
$p_{atm} = 1.013 \times 10^5$ Pa	$\rho_{atm} = 1.225$ kg	$T_{atm} = 15.1\ ^oC$

Some Liquid properties

Liquid	T (^{o}C)	ρ (kgm^{-3})	γ kNm^{-3}	μ (Nsm^{-2}) (kg m^{-1}s^{-1})	ν (m^{2}s^{-1})	E_v Nm^{-2}
Ethyl Alcohol	20	789	7.74	1.19×10^{-3}	1.51×10^{-6}	1.06×10^{9}
Gasoline	15.6	680	6.67	3.1×10^{-4}	4.6×10^{-7}	1.3×10^{9}
SeaWater	15.6	1030	10.1	1.20×10^{-3}	1.17×10^{-6}	2.34×10^{9}
SAE 30 oil	15.6	912	8.95	3.8×10^{-1}	4.2×10^{-4}	1.5×10^{9}
Water	15.6	999	9.80	1.12×10^{-3}	1.12×10^{-6}	2.15×10^{9}
Mercury	20.0	13600	133	1.57×10^{-3}	1.15×10^{-7}	2.85×10^{10}

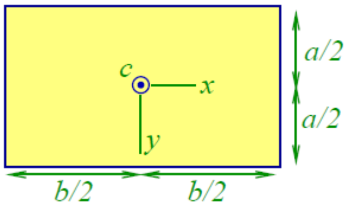
Some Gas properties (atmospheric pressure)

Gas	T (^{o}C)	ρ (kgm^{-3})	γ Nm^{-3}	μ (Nsm^{-2})	ν (m^{2}s^{-1})	R^* Jkg^{-1}K^{-1}
Air (standard)	15.0	1.23	12.0	1.79×10^{-5}	1.46×10^{-5}	286.9
N_2	20.0	1.16	11.4	1.76×10^{-5}	1.46×10^{-5}	296.8
Methane (natural gas)	20.0	0.667	6.54	1.10×10^{-5}	1.65×10^{-5}	518.3
Helium	20.0	0.166	1.63	1.94×10^{-5}	1.14×10^{-5}	2077
Carbon Dioxide	20.0	1.83	18.0	1.47×10^{-5}	9.03×10^{-6}	188.9

Quantity	Conversion	Factor
Acceleration	ft $s^{-2} \rightarrow$ m s^{-2}	0.3048
Area	$ft^2 \rightarrow m^2$	0.09290
Density	lbm $ft^{-3} \rightarrow kgm^{-3}$	16.02
Density	slugs $ft^{-3} \rightarrow kgm^{-3}$	515.4
Energy	BTU $\rightarrow$ J	1055
Energy	ft lb $\rightarrow$ J	1.356
Force	lb $\rightarrow$ N	4.448
Length	ft $\rightarrow$ m	0.3048
Length	in $\rightarrow$ m	0.02540
Length	mile $\rightarrow$ m	1609
Mass	lbm $\rightarrow$ kg	0.4536
Mass	slug $\rightarrow$ kg	14.59
Power	ft $lbs^{-1} \rightarrow$ W	1.356
Power	hp $\rightarrow$ W	745.7
Pressure	lb $ft^2 \rightarrow$ Pa	47.88
Pressure	lb in^2 (psi) $\rightarrow$ Pa	6895
Pressure	mm Hg (torr) $\rightarrow$ Pa	133.3
Pressure	bar $\rightarrow$ Pa	10^5
Specific Weight	lb $ft^{-3} \rightarrow$ N m^{-3}	157.1
Temperature	$^oC \rightarrow K$	$T_K = T_C + 273$
Temperature	$^oF \rightarrow {}^oC$	$T_C = \frac{5}{9}(T_F - 32)$
Velocity	ft $s^{-1} \rightarrow$ m s^{-1}	0.3048
Velocity	mph $\rightarrow$ m s^{-1}	0.4470
Velocity	km hr $\rightarrow$ m s^{-1}	0.2777
Volume	$ft^3 \rightarrow m^3$	0.02832
Volume	liter $\rightarrow m^3$	10^{-3}
Volume	$in^3 \rightarrow m^3$	0.01639×10^{-3}
Volume	gal $\rightarrow m^3$	3.785×10^{-3}
Volume Flowrate	$ft^3/s \rightarrow m^3/s$	2.832×10^{-2}
Volume Flowrate	$gal^3/min \rightarrow m^3/s$	6.309×10^{-5}

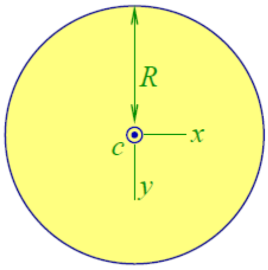
Rectangle

$$A = ba$$
$$I_{xc} = ba^3/12$$
$$I_{yc} = ab^3/12$$
$$I_{xyc} = 0$$



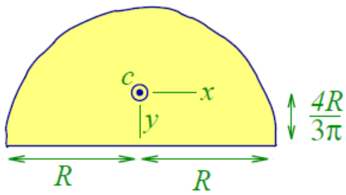
Circle

$$A = \pi R^2$$
$$I_{xc} = I_{yc} = \pi R^4/4$$
$$I_{xyc} = 0$$



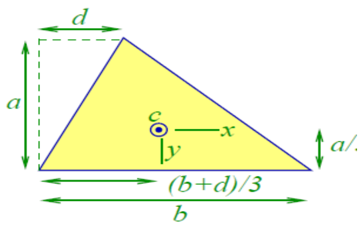
Half-circle

$$A = \pi R^2/2$$
$$I_{xc} = 0.1098R^4$$
$$I_{yc} = 0.3927R^4$$
$$I_{xyc} = 0$$



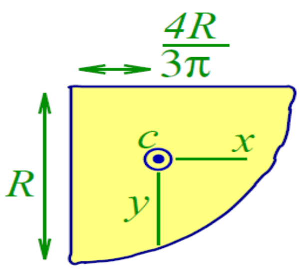
Triangle

$$A = ba/2$$
$$I_{xc} = ba^3/36$$
$$I_{xyc} = ba^2(b - 2d)/72$$



Quarter Circle

$$A = \pi R^2/4$$
$$I_{xc} = I_{yc} = 0.05488R^4$$
$$I_{xyc} = -0.01647R^4$$



I_{xyc} is only non-zero if the shape does not have a bilateral symmetry.