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INSTRUCTOR (**Check One Above**)

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MECH-422 ENERGY SYSTEMS LABORATORY

Midterm Exam

November 3, 2004

Instructions:

1. Write your name at the top of <u>each</u> page and check your Lab Instructor's name.
2. This exam is open-book, open notes/manual. However, **no sharing of material during the exam is allowed among students.**
3. You have 2 hours. This exam consists of 10 multiple-choice problems/questions (5 points each) and 2 work-out problems (25 points each).
4. Should questions arise, remain at your desk and raise your hand.
5. **For multiple-choice problems**, if differences in round-off procedures result in slight numerical differences between the answers given and your results, **circle the closest answer.**

Barometric pressure =14.7 psia=101 kPa for all problems (unless specified otherwise)

$g = 9.81\ m/s^2 = 32.2\ ft/s^2$ $lb_f = 32.2\ lb_m\text{-}ft/s^2$ specific heat ratio for air, k=1.4

ideal gas law: $P = \rho RT$,   R = 0.287 kJ/(kg K) for air

density of water, $\rho = 1000\ kg/m^3 = 1.94\ slugs/ft^3 = 62.4\ lb_m/ft^3$

density of air = $1.23\ kg/m^3 = 0.00239\ slugs/ft^3 = 0.075\ lb_m/ft^3$

density of mercury = $13{,}550\ kg/m^3$

dynamic viscosity of air = $1.79 \times 10^{-5}\ N\,s/m^2 = 3.82 \times 10^{-7}\ lb_f\,s/ft^2$

dynamic viscosity of water = $1.79 \times 10^{-3}\ N\,s/m^2 = 2.037 \times 10^{-5}\ lb_f\,s/ft^2$

1 Btu/s = 1.055 kW   550 ft lb_f/s = 1 hp

1 kg = 0.068522 slugs   1 gallon = 0.1337 ft^3 1 liter = $3.53 \times 10^{-2}\ ft^3 = 10^{-3}\ m^3$

universal gas constant, R_u = 8.314 kJ/Kmol.K

molecular mass of hydrogen: 2.016

molecular mass of oxygen: 31.999

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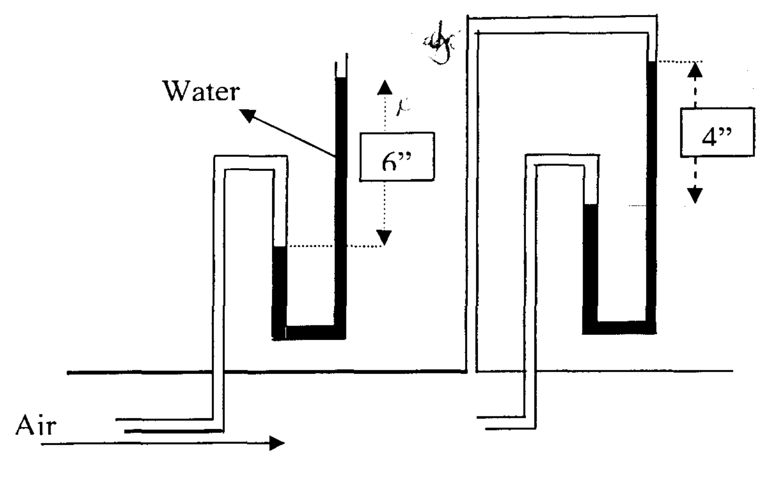
Problem 1 (5 points)

The volume of a cone in terms of its radius at the base and its height is given by $V = \frac{1}{3}\pi R^2 h$. The radius was measured to be 2 in ± 0.01 and the height was measured to be 8 in ± 0.01. The most pessimistic relative and absolute errors in the measurement of volume are:

(a)	0.88%	33.510 in^3
(b)	1.13%	0.377 in^3
(c)	0.01%	3.351 in^3
(d)	11.25%	3.770 in^3

Problem 2 (5 points)

With reference to the following figure, the stagnation, static, and dynamic pressures are…



a. 6”, 4” and 6” of water.
b. 10”, 4” and 2” of water.
c. 4”, 10” and 6” of water.
d. 6”, 2” and 4” of water.

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Problem 3 (5 points)

In the pipe flow experiment, the pressure drop between two points that are 5 ft apart is measured to be 2" of water. If the diameter of the pipe is 1.75" and the average velocity is calculated to be 80 ft/sec, the friction factor for the pipe is about...........

(a) 0.04 (b) 0.48 (c) 0.20 (d) 0.02

Problem 4 (5 points)

In the **Pipe Flow** experiment, the average velocity of air is calculated to be 80 ft/sec. The static pressure after the fan is measured to be 4.5" of water. Taking $\alpha = 1.0$, what is the fan's head?

(a) 304 ft (b) 100 ft (c) 404 ft (d) 204 ft

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Problem 5 (5 points)

For the **Flow Meters** experiment, the following data is available:

Pipe diameter = 3”
Laminar flow meter reading: 2.6” of water

If the laboratory is at 70 °F, what is the **actual mass flow rate** of the air as determined by the laminar flow meter? **ρ_{air} @ 70 °F and 530 °R= 0.076314 lbm/ft^3**

(a) 35.000 lb_m/min
(b) 0.583 lb_m/min
(c) 2.671 lb_m/min
(d) 6.977 lb_m/min

Problem 6 (5 points)

In the **Flow Meters** experiment, the following data is available:

Pipe diameter = 3”
Venturi throat diameter = 1.2” ΔP= 1.5” of water for the Venturi

What is the **ideal** volumetric flow rate?

(a) 94.5 ft^3/min (b) 67.0 ft^3/min (c) 1.6 ft^3/min (d) 79 ft^3/min

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Problem 7 (5 points)

Which of the following statements is correct?

(a) Venturi meter is the best flow meter because it gives the minimum pressure drop.
(b) Orifice plate yields the most accurate volumetric flow rate because of the sudden change of area.
(c) The elbow is the least effective flow measurement device because it gives the minimum pressure drop.
(d) The elbow is the least effective flow measurement device because the flow turns by 90°.

Problem 8 (5 points)

In the **Centrifugal Pump** experiment, the following data are taken:

Pump head = 4.0 m
Q = 0.3 lit/sec
Speed = 2000 rpm
Torque = 0.2 Nm

The efficiency of the pump is about……..

(a) 0.46% (b) 28% (c) 4.6% (d) 46%

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Problem 9 (5 points)

The specific speed of a pump represents:

a. Speed required to produce unit head at unit volumetric flow rate
b. A combination of C_Q and C_H coefficients to obtain the speed of the pump
c. The speed of the pump per unit mass of the flow rate
d. The speed of the pump to produce a required head

Problem 10 (5 points)

In the **Centrifugal Pump** experiment the following data is available:

Speed = 2000 rpm
Torque = 0.2 Nm
Impeller diameter = 5.5 cm

The power coefficient is about….

(a) 6.605 (b) 0.005 (c) 0.02 (d) 0.009

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Problem 12 (25 points)

The data below were obtained in the test cell for the **actual** engine used in the **Road Load Simulation** experiment:

road speed mph	road speed km/h	engine power kW	engine speed rpm	engine torque N.m	fuel flow rate kg/hr	air flow rate kg/hr	exhaust temp. C	coolant inlet temp. C	coolant outlet temp. C	coolant flow rate L/min
4th gear										
70	112.7	25.8	2113.0	116.6	7.1	102.0	602.2	7.5	65.0	5.3

Determine:

(a) The actual thermal efficiency of this engine (%).

(b) Energy carried away by the exhaust gases as a percentage of the heat released by the fuel (%).

(c) Heat carried away by the coolant as a percentage of the heat released by the fuel (%).

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Problem 11 (25 points)

The following data were collected for the PEM Fuel Cell Systems actually used in the Lab:

H_2 Flow Rate (ml/min)			150	Air Flow Rate (ml/min)		1000
H_2 Supply Pressure (psig)			20	Air Supply Pressure (psig)		20
Stack Temp. (°C)			50	Hydrogen Humidifier Temp. (°C)		30
Air Humidifier Temp. (°C)			20	Total Electrode Area (cm^2)		16
Current	**Cell Potential (V)**			**Temp. (°C)**		
(Amps)	Cell 1	Cell 2	Cell 3	Cell 1	Cell 2	Cell 3
10	0.4	0.5	0.0	53.8	56.0	55.3

a. What is the actual **stack** efficiency (%).

X

b. Estimate the theoretical open-cell voltage.

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