UNIVERSITY OF FORT HARE

PHY122F

SUPPLEMENTARY EXAMINATIIONS
JAN / FEB 2018

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Time: 3 HOURS

Subject: FLUIDS, HEAT AND THERMODYNAMICS

Marks: 100

This paper consists of 8 pages including cover page

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Instructions

- Answer any five (5) questions of your choice
- Read the question more than once and clearly write down your data.
- On problem solving, specify useful definitions and draw clearly labeled diagrams.

Formula sheet (PHY122F)

$P = \frac{F}{A}$, $P = P_0 + \rho gh$, $\rho = \frac{m}{V}$, $P_1 = P_2$, $A_1 \Delta x_1 = A_2 \Delta x_2$, $F_1 \Delta x_1 = F_2 \Delta x_2$, $B = \rho V g$,

$A_1 v_1 = A_2 v_2$, $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$, $T_c = T - 273.15$, $T_f = \frac{9}{5}T_c + 32$,

$\Delta T_c = \Delta T = \frac{5}{9}\Delta T_f$ $\Delta L = \alpha L_i \Delta T$, $\Delta A = 2\alpha A_i \Delta T$, $\Delta V = \beta V_i \Delta T$, $\beta = 3\alpha$, $n = \frac{m}{M}$, $n = \frac{N}{N_A}$,

$PV = nRT$, $PV = Nk_B T$, $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$, $Q = mc\Delta T$, $Q_{cold} = -Q_{hot}$, $Q = \pm mL$, $e = \frac{W_{eng}}{Q_h}$,

$W = -P(V_f - V_i)$, $\Delta E_{int} = Q + W$, $W = nRT \ln\left(\frac{V_i}{V_f}\right)$, $Q_{net} = Q_h - Q_c$, $W_{eng} = Q_{net}$,

$e = 1 - \frac{Q_c}{Q_h}$, $COP_c = \frac{Q_c}{W_{eng}}$, $COP_h = \frac{Q_h}{W_{eng}}$, $e_c = 1 - \frac{T_c}{T_h}$, $e = 1 - \frac{1}{\left(V_1/V_2\right)^{\gamma-1}}$, $dS = \frac{dQ_r}{T}$,

$\Delta S = \int_i^f \frac{dQ_r}{T}$, $\Delta S = nr \ln\left(\frac{V_i}{V_f}\right)$, $S = k_b \ln W$.

Constants:

$N_A = 6.02\times10^{23}$, $R = 8.314 J/mol$, $R = 0.08214 L.atm/mol.K$, $k_B = 1.38\times10^{-23} J/K$,

$1.00 atm = 1.013\times10^5\, Pa$

TABLE 20.2

Latent Heats of Fusion and Vaporization

Substance	Melting Point (°C)	Latent Heat of Fusion (J/kg)	Boiling Point (°C)	Latent Heat of Vaporization (J/kg)
Helium	−269.65	5.23×10^3	−268.93	2.09×10^4
Nitrogen	−209.97	2.55×10^4	−195.81	2.01×10^5
Oxygen	−218.79	1.38×10^4	−182.97	2.13×10^5
Ethyl alcohol	−114	1.04×10^5	78	8.54×10^5
Water	0.00	3.33×10^5	100.00	2.26×10^6
Sulfur	119	3.81×10^4	444.60	3.26×10^5
Lead	327.3	2.45×10^4	1 750	8.70×10^5
Aluminum	660	3.97×10^5	2 450	1.14×10^7
Silver	960.80	8.82×10^4	2 193	2.33×10^6
Gold	1 063.00	6.44×10^4	2 660	1.58×10^6
Copper	1 083	1.34×10^5	1 187	5.06×10^6

TABLE 14.1

Densities of Some Common Substances at Standard Temperature (0°C) and Pressure (Atmospheric)

Substance	ρ (kg/m^3)	Substance	ρ (kg/m^3)
Air	1.29	Ice	0.917×10^3
Aluminum	2.70×10^3	Iron	7.86×10^3
Benzene	0.879×10^3	Lead	11.3×10^3
Copper	8.92×10^3	Mercury	13.6×10^3
Ethyl alcohol	0.806×10^3	Oak	0.710×10^3
Fresh water	1.00×10^3	Oxygen gas	1.43
Glycerin	1.26×10^3	Pine	0.373×10^3
Gold	19.3×10^3	Platinum	21.4×10^3
Helium gas	1.79×10^{-1}	Seawater	1.03×10^3
Hydrogen gas	8.99×10^{-2}	Silver	10.5×10^3

TABLE 19.1

Average Expansion Coefficients for Some Materials Near Room Temperature

Material	Average Linear Expansion Coefficient (α) $(°C)^{-1}$	Material	Average Volume Expansion Coefficient (β) $(°C)^{-1}$
Aluminum	24×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Brass and bronze	19×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Acetone	1.5×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	3.2×10^{-6}	Mercury	1.82×10^{-4}
Lead	29×10^{-6}	Turpentine	9.0×10^{-4}
Steel	11×10^{-6}	Gasoline	9.6×10^{-4}
Invar (Ni–Fe alloy)	0.9×10^{-6}	Air[a] at 0°C	3.67×10^{-3}
Concrete	12×10^{-6}	Helium[a]	3.665×10^{-3}

[a] Gases do not have a specific value for the volume expansion coefficient because the amount of expansion depends on the type of process through which the gas is taken. The values given here assume the gas undergoes an expansion at constant pressure.

Substance	Specific Heat c J/kg · °C	cal/g · °C
Elemental solids		
Aluminum	900	0.215
Beryllium	1 830	0.436
Cadmium	230	0.055
Copper	387	0.092 4
Germanium	322	0.077
Gold	129	0.030 8
Iron	448	0.107
Lead	128	0.030 5
Silicon	703	0.168

Substance	Specific Heat c J/kg · °C	cal/g · °C
Other solids		
Brass	380	0.092
Glass	837	0.200
Ice (−5°C)	2 090	0.50
Marble	860	0.21
Wood	1 700	0.41
Liquids		
Alcohol (ethyl)	2 400	0.58
Mercury	140	0.033
Water (15°C)	4 186	1.00
		0.48

TABLE 21.2

Molar Specific Heats of Various Gases

Gas	Molar Specific Heat (J/mol · K)[a] C_P	C_V	$C_P - C_V$	$\gamma = C_P/C_V$
Monatomic gases				
He	20.8	12.5	8.33	1.67
Ar	20.8	12.5	8.33	1.67
Ne	20.8	12.7	8.12	1.64
Kr	20.8	12.3	8.49	1.69
Diatomic gases				
H_2	28.8	20.4	8.33	1.41
N_2	29.1	20.8	8.33	1.40
O_2	29.4	21.1	8.33	1.40
CO	29.3	21.0	8.33	1.40
Cl_2	34.7	25.7	8.96	1.35
Polyatomic gases				
CO_2	37.0	28.5	8.50	1.30
SO_2	40.4	31.4	9.00	1.29
H_2O	35.4	27.0	8.37	1.30
CH_4	35.5	27.1	8.41	1.31

[a] All values except that for water were obtained at 300 K.

Question 1 (Fluid Mechanics) [20]

1.1. Scientists have found evidence that Mars may once have had an ocean 0.500 km deep. The acceleration due to gravity on Mars is 3.71 m/s^2.

1.1.1. What would be the gauge pressure at the bottom of such an ocean, assuming it was fresh water? (2)

1.1.2. To what depth would you need to go in the earth's ocean to experience the same gauge pressure? (3)

1.2. A table-tennis ball has a diameter of 3.80 cm and averaged density of 0.0840 g/cm^3. What force is required to hold it completely submerged under water? (5)

1.3. State Pascal's law in words. (2)

1.4. A hydraulic jack is used to lift a 1200 kg car on a piston of diameter 30 cm .

1.4.1. How large a force is needed to push down the smaller piston if its diameter is 2 cm? (4)

1.4.2. By how much is the car lifted with a single push, assuming that the small piston moves 0.50 m? (4)

Question 2 (Temperature and Thermal Expansion) [20]

2.1. State the Zeroth law of thermodynamics and use it to explain whether it is possible for the two objects to be in thermal equilibrium if they are not in physical contact with each other. (3)

2.2. You put a bottle of soft drink in a refrigerator and leave it until its temperature has dropped by 10.0 K. What is its temperature change in Fahrenheit and Celsius degrees? (4)

2.3. A liquid has a density ρ_i.

2.3.1. Show that the change in density of a substance, when the temperature changes by ΔT, is given by $\Delta\rho = -\rho_f \beta \Delta T$. (4)

2.3.2. What does the negative sign signify? (1)

2.3.3. What is the fractional change in density of a lead sphere whose temperature decreases from 25.0 °C to -40.0 °C? (4)

2.4. A copper cylinder is initially at 20.0 °C. At what temperature will its volume be 0.150% larger than it is at 20.0 °C? (5)

Question 3 (Calorimetry and Phase Change) [20]

3.1. A physics student wants to cool 0.25 kg of Diet Omni-Cola (mostly water), initially at 25.0°C, by adding ice initially at -20.0°C. How much ice should she add so that the final temperature will be 0°C with all the ice melted if the heat capacity of the container may be ignored? (10)

3.2. An insulated beaker with negligible mass contains 0.250 kg of water at a temperature of 75.0°C. How many kilograms of ice at a temperature of -20.0°C must be dropped into the water to make the final temperature of the system 30.0°C? (5)

3.3. A copper calorimeter can with mass 0.100 kg contains 0.160 kg of water and 0.0180 kg of ice in thermal equilibrium at atmospheric pressure. If 0.750 kg of lead at a temperature of 255°C is dropped into the calorimeter can, what is the final temperature? Assume that no heat is lost to the surroundings. (5)

Question 4 (First Law of thermodynamics and Application) [20]

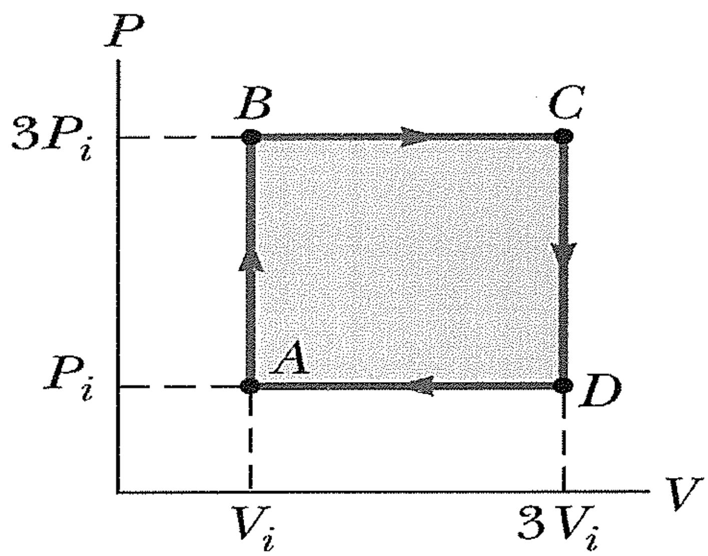
4.1. State first law of thermodynamics and use it to explain why the total energy of an isolated system is always constant. (8)

4.2. An ideal gas initially at P_i, V_i, and T_i is taken through a cycle as shown in figure below.

4.2.1. Find the net work done on the gas per cycle. (6)

4.2.2. What is the net energy added by heat to the system per cycle? (3)

4.2.3. Obtain a numerical value for the net work done per cycle for 1.00 mol of gas initially at 0 °C. (3)



Question 5 (Ideal Gases) [20]

5.1. In an internal combustion engine, air at atmospheric pressure and a temperature of 20.0 °C is compressed in the cylinder by a piston to $\frac{1}{9}$ of its original volume. Estimate the temperature of the compressed air, assuming the pressure reaches 40 atm. (4)

5.2. Calculate the density of oxygen at STP using ideal gas law. (4)

5.3. During the compression stroke of a certain gasoline engine, the pressure increases from 1.00 atm to 20.0 atm. If the process is adiabatic and the fuel-air mixture behaves as a diatomic ideal gas,

5.3.1. by what factor does the volume change and (3)

5.3.2. by what factor does the temperature change? (3)

5.3.3. Assuming the compression starts with 0.0160 mol of gas at 27.0°C, find the values of Q, W, and ΔE_{int} that characterize the process. (6)