

# UNIVERSITY OF FORT HARE

PHY122F

## SUPPLEMENTARY DEGREE EXAMINATIONS OCTOBER / NOVEMBER

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Time: 3 HOURS

Subject: FLUIDS, HEAT AND THERMODYNAMICS

Marks: 100

This paper consists of 8 pages, including the cover page.

**Internal Examiner**

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**Moderator**

MR. Someketa

**Instructions**

- Answer all questions five questions.
- Read the question more than once and write down your data.
- On problem-solving, specify useful definitions and draw clearly labeled diagrams.

**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  $3.71 \text{ m/s}^2$ .

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  $0.0840 \text{ g/cm}^3$ . 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  $\rho_l$ .

2.3.1. Show that the change in density of a substance, when the temperature changes by  $\Delta T$ , 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  $25.0\text{ }^\circ\text{C}$  to  $-40.0\text{ }^\circ\text{C}$ ? (4)

2.4. A copper cylinder is initially at  $20.0\text{ }^\circ\text{C}$ . At what temperature will its volume be 0.150% larger than it is at  $20.0\text{ }^\circ\text{C}$ ? (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  $25.0\text{ }^\circ\text{C}$ , by adding ice initially at  $-20.0\text{ }^\circ\text{C}$ . How much ice should she add so that the final temperature will be  $0\text{ }^\circ\text{C}$  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  $75.0\text{ }^\circ\text{C}$ . How many kilograms of ice at a temperature of  $-20.0\text{ }^\circ\text{C}$  must be dropped into the water to make the final temperature of the system  $30.0\text{ }^\circ\text{C}$ ? (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  $255\text{ }^\circ\text{C}$  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 Complete the following table:

	W	$\Delta E_{\text{int}}$	Q
Cyclic process			
Isovolumetric proces			
Adiabatic process			
Isothermal process			

(12)

4.2 A 2.00 mol sample of helium gas initially at 300 K and 0.400 atm is compressed isothermally to 1.20 atm. Noting that the helium behaves as an idea gas, find

4.2.1. the final volume of the gas, (3)

4.2.2. the work done on the gas, and (2)

4.2.3. the energy transferred by heat. (3)

**Question 5****(Heat Engines, Entropy, and the 2<sup>nd</sup> Law of Thermodynamics)**

[20]

5.1 Does the second law of thermodynamics contradict or correct the first law?  
(5)

5.2 State the Carnot's theorem. (3)

5.3 A heat engine takes in 360 J of energy from a hot reservoir and performs 25.0 J of work in each cycle. Find

- 5.3.1 the efficiency of the engine (2)
- 5.3.2 the energy expelled to the cold reservoir in each cycle. (2)
- 5.4 Discuss the change in entropy of a gas that expands
- 5.4.1 At constant temperature (4)
- 5.4.2 Adiabatically. (4)

### Formula sheet (PHY122F)

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

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

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

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

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

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

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

### Constants:

$$N_A = 6.02 \times 10^{23}, \quad R = 8.314 \text{ J/mol}, \quad R = 0.08214 \text{ L.atm/mol.K}, \quad k_B = 1.38 \times 10^{-23} \text{ J/K},$$

$$1.00 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$$

**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	$5.23 \times 10^3$	-268.93	$2.09 \times 10^4$
Nitrogen	-209.97	$2.55 \times 10^4$	-195.81	$2.01 \times 10^5$
Oxygen	-218.79	$1.38 \times 10^4$	-182.97	$2.13 \times 10^5$
Ethyl alcohol	-114	$1.04 \times 10^5$	78	$8.54 \times 10^5$
Water	0.00	$3.33 \times 10^5$	100.00	$2.26 \times 10^6$
Sulfur	119	$3.81 \times 10^4$	444.60	$3.26 \times 10^5$
Lead	327.3	$2.45 \times 10^4$	1750	$8.70 \times 10^5$
Aluminum	660	$3.97 \times 10^5$	2450	$1.14 \times 10^7$
Silver	960.80	$8.82 \times 10^4$	2193	$2.33 \times 10^6$
Gold	1063.00	$6.44 \times 10^4$	2660	$1.58 \times 10^6$
Copper	1083	$1.34 \times 10^5$	1187	$5.06 \times 10^6$

**TABLE 14.1****Densities of Some Common Substances at Standard Temperature (0°C) and Pressure (Atmospheric)**

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

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**TABLE 19.1****Average Expansion Coefficients for Some Materials Near Room Temperature**

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

<sup>a</sup> 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.

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Substance	Specific Heat $c$		Substance	Specific Heat $c$		
	J/kg · °C	cal/g · °C		J/kg · °C	cal/g · °C	
<i>Elemental solids</i>						
Aluminum	900	0.215	<i>Other solids</i>	Brass	380	0.092
Beryllium	1 830	0.436		Glass	837	0.200
Cadmium	230	0.055		Ice (-5°C)	2 090	0.50
Copper	387	0.092 4		Marble	860	0.21
Germanium	322	0.077		Wood	1 700	0.41
Gold	129	0.030 8		<i>Liquids</i>		
Iron	448	0.107		Alcohol (ethyl)	2 400	0.58
Lead	128	0.030 5		Mercury	140	0.033
Silicon	703	0.168		Water (15°C)	4 186	1.00
Silver	234	0.056		<i>Gas</i>		
				Steam (100°C)	2 010	0.48

**TABLE 21.2**

**Molar Specific Heats of Various Gases**

Gas	Molar Specific Heat (J/mol · K) <sup>a</sup>			$\gamma = C_p / C_v$
	$C_p$	$C_v$	$C_p - C_v$	
<i>Monatomic gases</i>				
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
<i>Diatomic gases</i>				
H <sub>2</sub>	28.8	20.4	8.33	1.41
N <sub>2</sub>	29.1	20.8	8.33	1.40
O <sub>2</sub>	29.4	21.1	8.33	1.40
CO	29.3	21.0	8.33	1.40
Cl <sub>2</sub>	34.7	25.7	8.96	1.35
<i>Polyatomic gases</i>				
CO <sub>2</sub>	37.0	28.5	8.50	1.30
SO <sub>2</sub>	40.4	31.4	9.00	1.29
H <sub>2</sub> O	35.4	27.0	8.37	1.30
CH <sub>4</sub>	35.5	27.1	8.41	1.31

<sup>a</sup> All values except that for water were obtained at 300 K.