UNIVERSITY OF FORT HARE

FLUIDS, HEAT, AND THERMODYNAMICS
PHY 114

DEGREE EXAMINATIONS

MAY / JUNE

YEAR

2025

Time:	**2 hours**
Subject:	**PHY 114**
Marks:	**100**

This paper consists of 10 pages, including the cover page

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INSTRUCTIONS

Answer ALL Questions.
Useful information on the back page.
Round off your answers to TWO decimal places.

Question 1 [20]

1. How much heat must be absorbed by 375 grams of water to raise its temperature by 25°C? (5)
2. A 5.0 g copper sample is heated from 20°C to 80°C. How much energy is required? (5)
3. A gas in a cylinder is at a pressure of 1.01×10^5 Pa, and the piston has an area of 0.100 m^2. The piston moves up by 4.00 cm as heat is added. Calculate the work done by the gas on the surroundings. (5)
4. A container of yogurt provides 240 food Calories of energy. If the latent heat of vaporization of water at body temperature is 2.42×10^6 J/kg, calculate the mass of perspiration required to remove this energy. (5)

Question 2 [20]

1. The volume of liquid flowing per second is called the volume flow rate ***Q*** and has the units of $\frac{m^3}{s}$. The flow rate of a liquid through a hypodermic needle during an injection can be estimated with the following equation: $Q = \frac{\pi R^n (P_2 - P_1)}{8\eta L}$

The length and radius of the needle are *L* and *R*, respectively, both of which have the units of length, *L*. The pressures at opposite ends of the needle are P_2 and P_1, both of which have the units of $\frac{kg}{ms^2}$. The symbol η represents the viscosity of the liquid and has the units of $\frac{kg}{ms}$. The symbol π stands for *pi* and, like the number *8* and the exponent ***n***, has no dimensions. Using units' analysis, determine the value of ***n*** in the expression for ***Q***. (10)

2. An ideal gas absorbs 5000 J of heat and does 2000 J of work.

   (i) Find the change in internal energy. (5)

   (ii) If later 4500 J is lost from the internal energy and 7500 J is expelled as heat, calculate the change in volume, assuming constant pressure of 1.01×10^5 Pa. (5)

Question 3 [20]

1. Water moves through a constricted pipe in steady, ideal flow. At the lower point, the pressure $P_1 = 1.75 \text{ X } 10^4$ Pa and the pipe diameter is 6.00 cm. At another point y = 0.250 m higher, the pressure $P_2 = 1.20 \times 10^4$ Pa, and the pipe diameter is 3.00 cm. Find the speed of the flow

   i. In the lower section and

   ii. In the upper section

   iii. Find the volume flow rate through the pipe (10)

2. Show that the coefficient of volume expansion, β, is related to the coefficient of linear expansion, α, through the expression $\beta = 3\alpha$. (5)

3. The Concorde is 62 m long when its temperature is 23 °C. In flight, the outer skin of this supersonic aircraft can reach 105 °C due to air friction. The coefficient of linear expansion of the skin is 2×10^{-5} (°C)$^{-1}$.

   Find the amount by which the Concorde expands. (5)

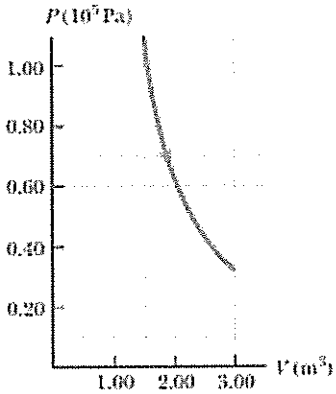
Question 4 (20)

1. An ideal gas absorbs 5.00×10^3 J of energy while doing 2.00×10^3 J of work on the environment during a constant pressure process. (a) Compute the change in the internal energy of the gas. (b) If the internal energy now drops by 4.50×10^3 J and 7.50×10^3 J is expelled from the system, find the change in volume, assuming a constant pressure process at 1.01×10^5 Pa. (5)

2. In a car engine operating at a frequency of 1.80×10^3 rev/min, the expansion of hot, high-pressure gas against a piston occurs in about 10 ms. Because energy transfer by heat typically takes a time on the order of minutes or hours, it's safe to assume little energy leaves the hot gas during the expansion. Find the work done by the gas on the piston during this adiabatic expansion by assuming the engine cylinder contains 0.100 moles of an ideal monatomic gas

that goes from 1.200 × 10^3 K to 4.00 x 10^2 K, typical engine temperatures, during the expansion. (5)

3. A monatomic ideal gas at an initial pressure of 1.01 × 10^5 Pa expands adiabatically from an initial volume of 1.50 m^3, doubling its volume. (a) Find the new pressure. (b) Sketch the PV diagram and estimate the work done on the gas.



(5)

4. A balloon contains 5.00 moles of a monatomic ideal gas. As energy is added to the system by heat (say, by absorption from the Sun), the volume increases by 25% at a constant temperature of 27.°C. Find the work W_{env} done by the gas in expanding the balloon, the thermal energy Q transferred to the gas, and the work W done on the gas. (5)

Question 5 (20)

1. State Carnot's theorem. (2)
2. A heat engine takes 360 J of energy from a hot reservoir and performs 25.0 J of work in each cycle. Find
   - i. The efficiency of the engine (2)
   - ii. The energy expelled to the cold reservoir in each cycle (2)
3. During one cycle, an engine extracts 2.00 x 10^3 J of energy from a hot reservoir and transfers 1.50 x 10^3 J to a cold reservoir.

   (a) Find the thermal efficiency of the engine. (2)

   (b) How much work does this engine do in one cycle? (2)

(c) How much power does the engine generate if it goes through four cycles in 2.50 s?

(2)

5. A 2.00-L container of leftover soup at a temperature of 323 K is placed in a refrigerator. Assume the specific heat of the soup is the same as that of water and the density is 1.25×10^3 kg/m3. The refrigerator cools the soup to 283 K. (a) If the COP of the refrigerator is 5.00, find the energy needed, in the form of work, to cool the soup. (b) If the compressor has a power rating of 0.250 hp, for what minimum length of time must it operate to cool the soup to 283 K? (The minimum time assumes the soup cools at the same rate that the heat pump ejects thermal energy from the refrigerator.) (8)

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Believing in you is the first secret to success!!!

<u>*Useful Information*</u>

1. *Linear Expansion:* $\Delta L = \alpha L_0 \Delta T$
2. *Heat to raise temperature:* $Q = mc\Delta T$
3. *Heat for change of phase:* $Q = mL$
4. *Volume of the sphere:* $V_{sphere} = \frac{4}{3}\pi r^3$
5. *Heat Conduction:* $Q = \frac{(kA\Delta T)t}{L}$
6. *Equation of Continuity:* $A_1 v_1 = A_2 v_2$
7. *Bernoulli's Equation:* $P_1 + \frac{1}{2}\rho {v_1}^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho {v_2}^2 + \rho g y_2$
8. *Density of water* = $1000\ kg/m^3$

Table 11.1 Mass Densities[a] of Common Substances

Substance	Mass Density ρ (kg/m^3)
Solids	
Aluminum	2700
Brass	8470
Concrete	2200
Copper	8890
Diamond	3520
Gold	19 300
Ice	917
Iron (steel)	7860
Lead	11 300
Quartz	2660
Silver	10 500
Wood (yellow pine)	550
Liquids	
Blood (whole, 37 °C)	1060
Ethyl alcohol	806
Mercury	13 600
Oil (hydraulic)	800
Water (4 °C)	1.000×10^3
Gases	
Air	1.29
Carbon dioxide	1.98
Helium	0.179
Hydrogen	0.0899
Nitrogen	1.25
Oxygen	1.43

[a] Unless otherwise noted, densities are given at 0 °C and 1 atm pressure.

TABLE 13–1 Coefficients of Expansion, near 20°C

Material	Coefficient of Linear Expansion, α $(C°)^{-1}$	Coefficient of Volume Expansion, β $(C°)^{-1}$
Solids		
Aluminum	25×10^{-6}	75×10^{-6}
Brass	19×10^{-6}	56×10^{-6}
Copper	17×10^{-6}	50×10^{-6}
Gold	14×10^{-6}	42×10^{-6}
Iron or steel	12×10^{-6}	35×10^{-6}
Lead	29×10^{-6}	87×10^{-6}
Glass (Pyrex®)	3×10^{-6}	9×10^{-6}
Glass (ordinary)	9×10^{-6}	27×10^{-6}
Quartz	0.4×10^{-6}	1×10^{-6}
Concrete and brick	$\approx 12 \times 10^{-6}$	$\approx 36 \times 10^{-6}$
Marble	$1.4\text{–}3.5 \times 10^{-6}$	$4\text{–}10 \times 10^{-6}$
Liquids		
Gasoline		950×10^{-6}
Mercury		180×10^{-6}
Ethyl alcohol		1100×10^{-6}
Glycerin		500×10^{-6}
Water		210×10^{-6}
Gases		
Air (and most other gases at atmospheric pressure)		3400×10^{-6}

Table 12.2 Specific Heat Capacities[a] of Some Solids and Liquids

Substance	Specific Heat Capacity, *c* J/(kg · C°)
Solids	
Aluminum	9.00×10^2
Copper	387
Glass	840
Human body (37 °C, average)	3500
Ice (−15 °C)	2.00×10^3
Iron or steel	452
Lead	128
Silver	235
Liquids	
Benzene	1740
Ethyl alcohol	2450
Glycerin	2410
Mercury	139
Water (15 °C)	4186

[a]Except as noted, the values are for 25 °C and 1 atm of pressure.

Table 12.3 Latent Heats[a] of Fusion and Vaporization

Substance	Melting Point (°C)	Latent Heat of Fusion, L_f (J/kg)	Boiling Point (°C)	Latent Heat of Vaporization, L_v (J/kg)
Ammonia	−77.8	33.2×10^4	−33.4	13.7×10^5
Benzene	5.5	12.6×10^4	80.1	3.94×10^5
Copper	1083	20.7×10^4	2566	47.3×10^5
Ethyl alcohol	−114.4	10.8×10^4	78.3	8.55×10^5
Gold	1063	6.28×10^4	2808	17.2×10^5
Lead	327.3	2.32×10^4	1750	8.59×10^5
Mercury	−38.9	1.14×10^4	356.6	2.96×10^5
Nitrogen	−210.0	2.57×10^4	−195.8	2.00×10^5
Oxygen	−218.8	1.39×10^4	−183.0	2.13×10^5
Water	0.0	33.5×10^4	100.0	22.6×10^5

[a]The values pertain to 1 atm pressure.

Table 13.1 Thermal Conductivities[a] of Selected Materials

Substance	Thermal Conductivity, k [J/(s · m · C°)]
Metals	
Aluminum	240
Brass	110
Copper	390
Iron	79
Lead	35
Silver	420
Steel (stainless)	14
Gases	
Air	0.0256
Hydrogen (H_2)	0.180
Nitrogen (N_2)	0.0258
Oxygen (O_2)	0.0265
Other Materials	
Asbestos	0.090
Body fat	0.20
Concrete	1.1
Diamond	2450
Glass	0.80
Goose down	0.025
Ice (0 °C)	2.2
Styrofoam	0.010
Water	0.60
Wood (oak)	0.15
Wool	0.040

[a] Except as noted, the values pertain to temperatures near 20 °C.