UNIVERSITY OF FORT HARE

HEAT AND THERMODYNAMICS

PHY 114F

DEGREE EXAMINATIONS

May / Jun

YEAR

2025

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

This paper consists of 6 pages, including the cover page

Internal Examiners

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Moderator

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INSTRUCTIONS

Answer ALL Questions.

Show ALL your calculations

Useful information on the back page.

Round off your answers to TWO decimal places.

Question 1

1.1 On a day when the temperature reaches 50°F, what is the temperature in degrees Celsius and in kelvins? **(2)**

1.2 The temperature gradient between the skin and the air is regulated by cutaneous (skin) blood flow. If the cutaneous blood vessels are constricted, the skin temperature and the temperature of the environment will be about the same. When the vessels are dilated, more blood is brought to the surface. Suppose during dilation the skin warms from 72.0°F to 84.0°F.
(a) Convert these temperatures to Celsius and find the difference.
(b) Convert the temperatures to Kelvin, again finding the difference. **(4)**

1.3 (a) A brass measuring tape measures 2.10 m at a temperature of 15°C. Determine the increase in length when the temperature has increased to 40°C. Assume the coefficient of linear expansion of brass to be 18 × 10−6 (°C)-1. **(3)**

(b) A brass shaft is 15.02 mm in diameter and must be inserted in a hole of diameter 15mm. Determine by how much the shaft must be cooled to make this possible, without using force. Take the coefficient of linear expansion of brass as 18 × 10−6 (°C)-1. **(3)**

(c) A rod of metal is measured at 285 K and is 3.521 m long. At 373 K the rod is 3.523 m long. Determine the value of the coefficient of linear expansion for the metal. **(3)**

1.4 State Archimede's Principle. **(2)**

1.5 (a) A ball of mass *10 kg* is held under the surface of a pool. The instant it is released, it has an instantaneous acceleration of 4 ms^{-2} toward the bottom of the pool. What is the volume of the ball? **(3)**

(b) What is the net force on a ball of mass *15 kg* and volume of $0.2m^3$ when it is submerged under water? $(g = 10ms^{-2};\ \rho_{water} = 1000\ kgm^{-3})$ **(2)**

Question 2

2.1 Suppose the pressure acting on the back of a swimmer's hand is 1.2x105 Pa. The surface area of the back of the hand is 8.4x10-3m2.
(a)Determine the magnitude of the force that acts on it. **(2)**
(b) Discuss the direction of the force. **(2)**

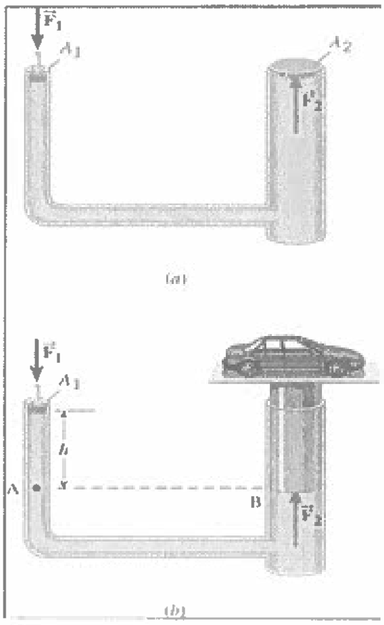
(c) A bar of soap, when weighed in air, has a weight of $W_{in\ air} = 5.2N$. When completely immersed in water, however, it has a weight of $W_{in\ water} = 3.7N$. Find the volume of the bar of soap. **(5)**

(d) A stonecutter's chisel has an edge area of $0.7\ cm^2$. If the chisel is struck with a force of 42 N, what is the pressure (in Nm^{-2}) exerted on the stone? **(3)**

2.2 Points A and B are located a distance of 5.50 m beneath the surface of the water. Find the pressure at each of these two locations. **(2)**

2.3 State Pascal's Principle **(2)**

2.4 The input piston has a radius of 0.0120 m and the output plunger has a radius of 0.150 m as shown in the diagram. The combined weight of the car and the plunger is 20500 N. Suppose that the input piston has a negligible weight, and the bottom surfaces of the piston and plunger are at the same level. What is the required input force?



(4)

Question 3

3.1 On a day when the temperature reaches 50°F, what is the temperature in degrees Celsius and in kelvins? (2)

3.2 The temperature gradient between the skin and the air is regulated by cutaneous (skin) blood flow. If the cutaneous blood vessels are constricted, the skin temperature and the temperature of the environment will be about the same. When the vessels are dilated, more blood is brought to the surface. Suppose during dilation the skin warms from 72.0°F to 84.0°F.
(a) Convert these temperatures to Celsius and find the difference.
(b) Convert the temperatures to Kelvin, again finding the difference. (4)

3.3 (a) A brass measuring tape measures 2.10 m at a temperature of 15°C. Determine the increase in length when the temperature has increased to 40°C. Assume the coefficient of linear expansion of brass to be 18 × 10−6 (°C)-1.

(3)

(b) A brass shaft is 15.02 mm in diameter and must be inserted in a hole of diameter 15mm. Determine by how much the shaft must be cooled to make this possible, without using force. Take the coefficient of linear expansion of brass as 18 × 10−6 (°C)-1. (3)

(c) A rod of metal is measured at 285 K and is 3.521 m long. At 373 K the rod is 3.523 m long. Determine the value of the coefficient of linear expansion for the metal. **(3)**

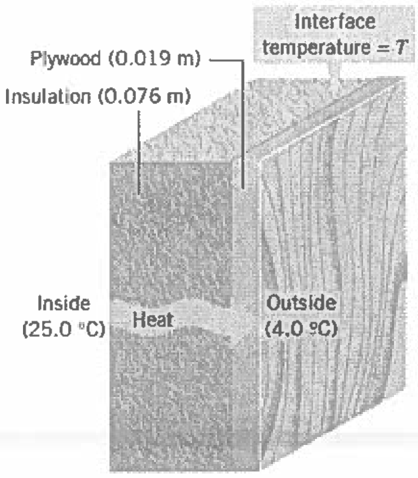
Question 4

4.1 What is Conduction? **(2)**

4.2 When excessive heat is produced within the body, it must be transferred to the skin and dispersed if the temperature at the body interior is to be maintained at the normal value of 37.0 °C. One possible mechanism for transfer is conduction through body fat. Suppose that heat travels through 0.030 m of fat in reaching the skin, which has a total surface area of 1.7 m^2 and a temperature of 34.0 °C. Find the amount of heat that reaches the skin in half an hour (1800 s). $k = 0.20$ *J/ (s .m.C°)*. **(3)**

4.3 One wall of a house consists of 0.019-m-thick plywood backed by 0.076-m-thick insulation, as Figure 13.10 shows. The temperature at the inside surface is 25.0 °C, while the temperature at the outside surface is 4.0 °C, both being constant. The thermal conductivities of the insulation and the plywood are, respectively, 0.030 and 0.080 J/(s .m.C°), and the area of the wall is 35 m^2.

(a) Find the heat conducted through the wall in one hour with the insulation. **(4)**
(b) Find the heat conducted through the wall in one hour without the insulation. **(2)**



4.4 State **the Stefan–Boltzmann Law of Radiation.** **(2)**

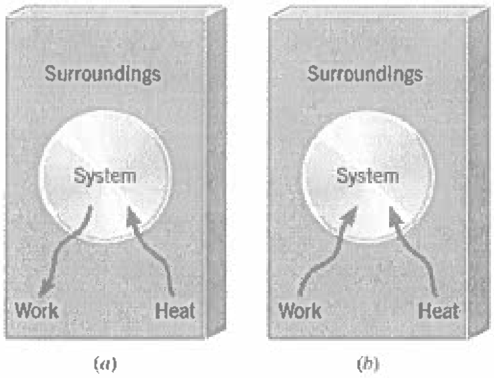
4.5 The supergiant star Betelgeuse has a surface temperature of about 2900 K (about one-half that of our sun) and emits a radiant power (in joules per second, or watts) of approximately 4×10^{30} W (about 10 000 times as great as that of our sun). Assuming that Betelgeuse is a perfect emitter (emissivity $e = 1$) and spherical, find its radius. **(3)**

Question 5

5.1 State the **Zeroth Law of Thermodynamics.** **(2)**

5.2 State the **First Law of Thermodynamics.** (3)

5.3 Figure 15.3 illustrates a system and its surroundings. In part *a*, the system gains 1500 J of heat from its surroundings, and 2200 J of work is done *by* the system on the surroundings. In part *b*, the system also gains 1500 J of heat, but 2200 J of work is done *on* the system by the surroundings. In each case, determine the change in the internal energy of the system and discuss what the signs indicate. (6)



5.4 The temperature of three moles of a monatomic ideal gas is reduced from $T_i = 540$ K to $T_f = 350$ K as 5500 J of heat flows into the gas, find:

(a) the change in internal energy. (2)

(b) the work done by the gas. (2)

5.5 Discuss the following Thermal processes:

(a) Isobaric (1)

(b) Isochoric (1)

(c) Isothermal (1)

(d) Adiabatic (1)

5.6 One gram of water is placed in the cylinder and the pressure is maintained at 2.0x 10^5Pa. The temperature of the water is raised by 31°C. The water is in the liquid phase and expands by the small amount of $1.0\text{x}10^{-8}m^3$. Find the work done and the change in internal energy. *c = 4186 J/(kg. C°)* (3)

5.7 An automobile engine has an efficiency of 22.0% and produces 2510 J of work. How much heat is rejected by the engine? (5)

USEFUL INFORMATION

$\Delta L = \alpha L_i \Delta T$, $\rho_{water} = 1000 \frac{kg}{m^3}$, $\rho = mv, P = \frac{F}{A'}$ (P_a = 1.013x 10^5 Pa), $P_2 = P_1 + \rho hg$, $V_{cylinder} = \pi r^2 h$,

$T_F = \frac{9}{5} T_C + 32°$, $F_B = \rho V g$, $T_C = T - 273.15$, $Q = \frac{(kA\Delta T)t}{L}$ $Q = e\sigma T^4 A t$, $\sigma = 5.67 \times 10^{-8}$ J/(s _m2 _K4)

is the Stefan–Boltzmann constant., $\Delta U = U_f - U_i = Q - W$, $U = \frac{3}{2} nRT$, R = 8.31 J/(mol.K), (P_a = 1.013x

10^5 Pa), $W = P \Delta V = P (V_f - V_i)$, $Q = cm\Delta T$, $W = nRT \ln\left(\frac{V_f}{V_i}\right)$, $e = \frac{|W|}{|Q_H|}$, $|Q_H| = |W| + |Q_C|$,

$e = 1 - \frac{|Q_C|}{|Q_H|}$