MACHAKOS UNIVERSITY

University Examinations 2022/2023

SCHOOL OF PURE AND APPLIED SCIENCES
DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION (SCIENCE)

BACHELOR OF EDUCATION (SPECIAL NEEDS)

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF SCIENCE (TELECOMMUNCATION AND INFORMATION TECHNOLOGY)

BACHELOR OF SCIENCE (MATHEMATICS)

SPH 203/SPT 203: THERMAL PHYSICS I

DATE: **TIME:**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

CONSTANTS

Stefan's constant $= 5.67 \times 10^{-8}\ \mathrm{W/m^2/K^4}$

Radius of Sun $= 7 \times 10^{8}$ m

Boltzmann constant $= 1.38 \times 10^{-23}\mathrm{J/K}$

Universal gas constant, R = 8.31 J mol-1 K-1

Avogadro's number $=6.02 \times 10^{23}\ \mathrm{mol^{-1}}$

SECTION A

QUESTION ONE (30 marks)

a) Define the following terminologies

i. Temperature gradient (2 marks)

ii. Coefficient of thermal conductivity (2 marks)

b) A liquid in glass thermometer uses a liquid whose volume varies with temperature according to the equation

$$V_\theta = V_0[1 + a\theta + b\theta^2]$$

Where V_θ and V_0 are the volumes of the liquid at $\theta^0\ C$ and $0^0\ C$ respectively. Parameters 'a' and 'b' are constants. If $\frac{a}{b} = 10^3$ calculate the reading on the liquid in glass scale when the actual temperature is $60^0\ C$ (5 marks)

c) The total translational kinetic energy of all the molecules of helium in a vessel at STP is 6.5×10^{-6} J. calculate the temperature in another vessel which contains twice the mass of helium and in which the total kinetic energy is 1.2×10^{-5}J. (3 marks)

d) State any three assumptions in the kinetic theory of gases. (3 marks)

e) One mole of an ideal gas initially kept in a cylinder at pressure 1 MPa and temperature 27°C is made to expand until its volume is doubled. How much work is done if the expansion is

(i) adiabatic and (3 marks

(ii) Isothermal? (3 marks)

f) A uniform metal bar 0.8 m long is properly insulated. One end is kept at 100^0C and the other end held at melting ice temperature. The cross-section area of the bar is 4×10^{-3} m^2 . The ice melts at a steady rate of 5.3×10^{-4} kg/s. Calculate the thermal conductivity of the metal bar if the specific latent heat of ice is 3.4×10^{-5} J/kg. (5 marks)

g) Determine the absolute temperature of a gas in which the average molecule of mass 8×10^{-26} kg is moving with RMS speed of 500 m/s. (4 marks)

SECTION B

QUESTION TWO (20 MARKS)

a) Define the following terms in calorimeters

i. Triple point of water (2 marks)

ii. Fundamental interval (2 marks)

b) A constant volume gas thermometer registers a pressure corresponding to 5 cmHg when in contact with water at the triple point. Calculate the pressure it reads when in contact with water at the normal boiling point. (4 marks)

c) Two perfectly lagged metal bars X and Y are arranged in (a) series and (b) in parallel. When the bars are in series, the 'hot' end of X is maintained at 90^0C and the cold end of Y is maintained at 30^0C . When the bars are in parallel the hot end of each is maintained at 30^0C . Calculate the ratio of the flow of heat in the parallel arrangement to that in series arrangement. The length of each bar is 'L' and the cross-section areas of each is 'A'. Thermal conductivity of X is 400 W/m/K and that of Y is 200 W/m/K. (8 marks)

d) The total external surface area of a dogs body is $0.8\ \mathrm{m}^2$ and the body temperature is 30^0C. At what rate is it losing heat by radiation when it is in a room whose temperature is 17^0C. (Assume the dog is black body.) (4 marks)

QUESTION THREE (20 marks)

a) Define the following type of heat flow in terms of the physical processes involved

i. Conduction (2 marks)

ii. Convection (2 marks)

iii. Radiation (2marks)

b) An ideal gas has an initial pressure of 20pa and a volume of 1 m^3. It is expanded to a final volume of $3\ \mathrm{m}^3$ and a final pressure of 5 Pa. Determine the heat energy transferred to/from the gas. (4 marks)

c) Two kg of air experiences the three-process cycle shown in Fig. 1. Calculate the net work done. (4 marks)

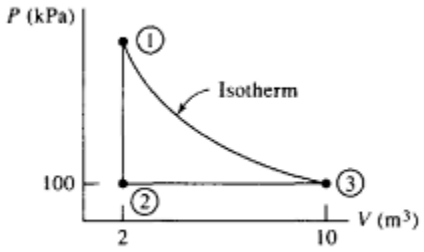

Figure 1

d) Given the equation $PV = RT$ for one mole of a gas with mass *m* and mean speed $\bar{c}$ show that

$$\frac{1}{2}m\bar{c}^2 = \frac{3}{2}k_B T$$

Where k_B is the Boltzmann constant and T is the absolute temperature (6 marks)

QUESTION FOUR (20 marks)

a) Define the following terms

i. Black body (2 marks)

ii. Emissivity (2 marks)

b) A coil has a resistance of $2.0\,\Omega$, $2.3\,\Omega$ and $3.0\ \Omega$ at temperatures 0^0C, 100^0C and T respectively. Determine the value of T on the scale defined by this coil. (4 marks)

c) State two advantages of a thermoelectric thermometer over a liquid-in-glass thermometer. (2 marks)

d) Calculate the root men square speed of hydrogen gas molecules given that the density of hydrogen at STP is $0.09\ \mathrm{kg/m^3}$. (4 marks)

e) The energy arriving per unit area on the earth's surface per second from the sun is $1.34 \times 10^3\ \mathrm{W}/m^2$. The average distance from the sun to the earth is 215 times greater than radius of the sun. Estimate the surface temperature of the sun assuming that both sun and the earth are black bodies. (6 marks)

QUESTION FIVE (20 marks)

a) Define the following processes in thermodynamics

i. Isochoric process (2 marks)

ii. Adiabatic process (2 marks)

b) Three metal rods made of copper, aluminum, and brass is each 15 cm long and 2.5 cm in diameter. The rods are placed end to end with aluminum between the other two (series). The free end of copper and brass are maintained at $100^0\ C$ and $0^0 C$ respectively. Calculate the equilibrium temperature at copper-aluminum junction and aluminum-brass junction. Assume the thermal conductivity of copper is twice that of aluminum and four times that of brass.

(5 marks)

c) Explain the Prevost's theory of heat exchanges (3 marks)

d) Assuming that the total surface area of a human body is 1.2 m^2 and the surface temperature is $30^0 C$, Calculate the total ate of radiation of energy of the human body. (3 marks)

e) Assume an ideal gas for which $\gamma = 1.5$ initially at 1 atmosphere pressure. The gas is compressed to one half of its original volume adiabatically. Calculate its final pressure.

(5 marks)