THE COPPERBELT UNIVERSITY

IN ASSOCIATION WITH

THE TECHNICAL AND VOCATIONAL TEACHERS' COLLEGE

BACHELOR OF SCIENCE IN MATHEMATICS AND SCIENCE WITH EDUCATION

THIRD YEAR - ODL

PROPERTIES OF MATTER AND THERMAL PHYSICS (PHY 340)

DECEMBER 2022 PROMOTIONAL EXAMINATION

TOTAL MARKS – 100%

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS AND INFORMATION TO CANDIDATES

1. All questions carry equal marks of 20 marks each.
2. The marks are shown in brackets.
3. This paper contains seven questions. Answer **any five** questions of your choice.
4. Show clearly all the necessary calculations.
5. Marks will be awarded for neat and well-drawn diagrams.
6. Clearly indicate on the answer booklet cover page which questions you have attempted.
7. Non-programmable scientific calculators are allowed.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO

WHEREVER NECESSARY USE:

$g = 9.81 m/s^2$

$c = 3.0 \times 10^8 m/s$

$1eV = 1.60 \times 10^{-19} J$

$1cal = 4.184 J$

$G = 6.67 \times 10^{-11} Nm^2/kg^2$

$1Ci = 3.7 \times 10^{10} Bq$

$\mu_0 = 4\pi \times 10^{-7} Tm/A$

$\varepsilon_0 = 8.85 \times 10^{-12} F/m$

$m_e = 9.11 \times 10^{-31} kg$

$k_e = 8.99 \times 10^9 Nm^2/C^2$

$e = 1.60 \times 10^{-19} C$

$\hbar = 1.05 \times 10^{-34} Js$

$R_H = 1.097 \times 10^7 m^{-1}$

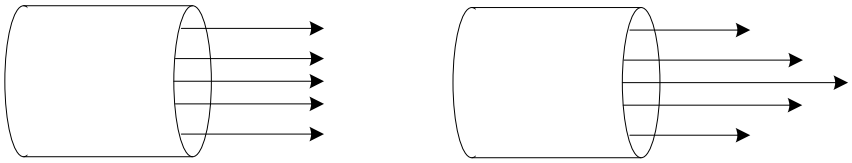
$\sigma = 5.669 \times 10^{-8} W/m^2 K^4$

$h = 6.626 \times 10^{-34} Js$

Question One

a. Define viscosity and write its mathematical expression. [3 marks]

b. Explain figures A and B in relation to viscosity [4 marks]



A B

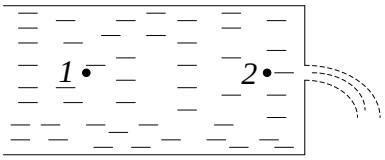
c. Each second, 1088 m^3 of water flows over the 110 m wide cliff of part of the Victoria Falls. The water is approximately 2 m deep as it reaches the cliff. Estimate its speed at that instant. [3 marks]

d. A water hose 2.50 cm in diameter is used by a gardener to fill a 30.0 liter bucket. The gardener notices that it takes 1.00 minute to fill the bucket. A nozzle with an opening of cross-sectional area 0.500 cm^2 is then attached to the hose. The nozzle is held so that water is projected horizontally from a point 1.00 m above the ground. Over what horizontal distance can the water be projected? [10 marks]

Question Two

a. State Bernoulli's equation and write its mathematical expression. [2 marks]

b. A water tank springs a leak at position 2 in the figure below, where the water pressure is 500 kPa. What is the velocity of escape of the water through the hole? [5 marks]



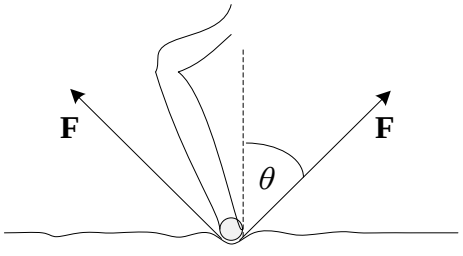
c. Derive Bernoulli's equation with the aid of a diagram. [13 marks]

Question Three

a. Differentiate between adhesive and cohesive forces. [2 marks]

b. Derive, with the aid of a diagram, an expression for the height h, of a fluid in a capillary tube where adhesive forces dominate cohesive forces. [6 marks]

c. When an insect steps onto the water with all six legs, a depression is formed in the water around each foot, as shown in in the figure below. The surface tension of the water produces upward forces on the water that tend to restore the water surface to its normally flat shape. Assuming that the insect's "foot" is spherical and that it has mass of 2.0×10^{-5} kg and the radius of each foot is 1.5×10^{-4} m, find the angle θ.



[12 marks]

Question Four

a. Define heat and give its SI base unit. [4 marks]

b. Stefan's law, $P = \sigma AeT^4$ states that the rate at which an object radiates energy is proportional to the fourth power of its absolute temperature. State the SI unit of each of the variables in the law. [10 marks]

c. The fundamental modes of heat transfer are conduction, convection and radiation. Explain each of these heat transfer processes. [6 marks]

Question Five

a. Define specific heat capacity. [2 marks]

b. How much heat is required to raise the temperature of 250mL of water from 20.0°C to 35.0°C? How much heat is lost by the water as it cools back down to 20.0°C? $c_{water} = 1.00 cal/g°C$ [6 marks]

c. Two identical metal plates (mass, m and specific heat, c) have different temperatures; one is at 20°C and the other is at 90°C. They are placed in good thermal contact. What is their final temperature? [5 marks]

d. An ideal gas absorbs 5.00×10^3J of energy while doing 2.00×10^3J of work on the environment during a constant pressure process.

i. Compute the change in the internal energy of the gas. [3 marks]

ii. If the internal energy now drops by 4.50×10^3J and 7.50×10^3J is expelled from the system, find the change in volume, assuming a constant pressure process at 1.01×10^5Pa. [4 marks]

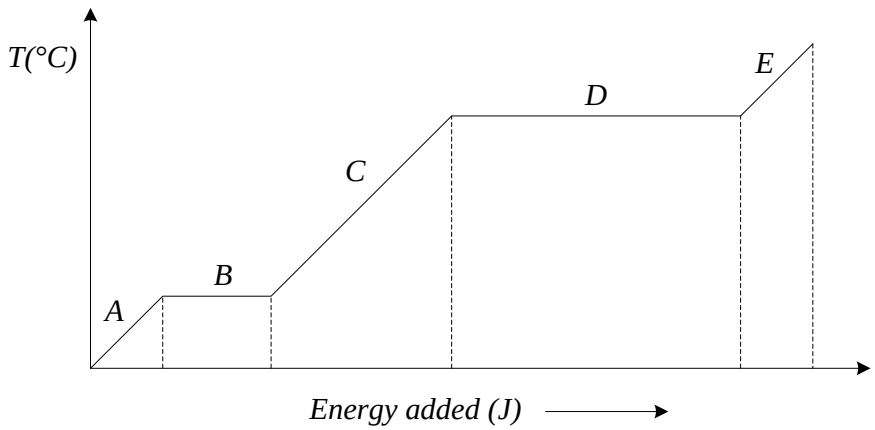
Question Six

a. What is phase change in thermodynamics? [2 marks]

b. Mention four examples of phase changes. [4 marks]

c. Determine the temperature T_f that results when 150g of ice at 0°C is mixed with 300g of water at 50°C. $L_{f(ice)} = 80 cal/g$, $c_{water} = 1.00 cal/g°C$ [4 marks]

d. The diagram below shows a plot of temperature versus energy added when 1.0g of ice initially at -30°C is converted to steam at 120.0°C.



Describe the phase changes A, B, C, D and E. [10 marks]

Question Seven

a. State the second law of thermodynamics in three ways. [6 marks]

b. Twenty gram of ice at 0°C melts to water with no change in temperature. By how much does the entropy of the 20g mass change in this process? $L_{f(ice)} = 80 cal/g$ [4 marks]

c. Find the change in entropy of 0.30g of lead when it melts at 327°C. Lead has a latent heat of fusion of 2.00×10^4J/kg. [4 marks]

d. A block of ice at 273K is in thermal contact with a container of steam at 373K, converting 25.0g of ice to water at 273K while condensing some of the steam to water at 373K. find;

i. the change in entropy of ice. $L_{f(ice)} = 3.33\times10^5 J/kg$ [2 marks]

ii. the change in entropy of the steam. [2 marks]

iii. the change in entropy of the universe. [2 marks]

END OF EXAMINATION