**PHY1506**

(477730)

October/November 2015

ELECTROMAGNETISM AND HEAT (PHYSICS)

Duration 2 Hours

100 Marks

EXAMINERS :

FIRST :

PROF ML LEKALA

SECOND

MR T TSHUMA

Use of a non-programmable pocket calculator is permissible.

Closed book examination.

This examination question paper remains the property of the University of South Africa and may not be removed from the examination venue.

Instructions:

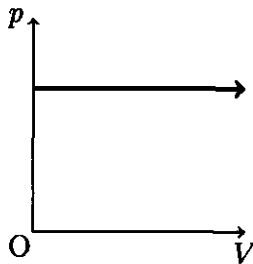
- This examination paper consists of eight (8) pages
- The paper consists of two sections, **Section A(30%)** and **Section B(70%)**
- Answer **Section A (Multiple choice)** on the examination mark reading sheet
- Answer **Section B(Written solutions)** on the examination answer book
- For the Written solutions, please show **all** the steps in carrying out the calculations
- The mark allocated to each question is indicated in brackets to the right
- The information given at the end of **Section B** may be used without proof.

[Turn Over]

SECTION A (Multiple Choice Questions)
(Each question carries 3 marks TOTAL. [30])

1 The process shown in the pV diagram in the figure is an

- 1) adiabatic expansion
- 2) isobaric expansion
- 3) isochoric expansion
- 4) isothermal expansion
- 5) isochoric compression.



2 When a fixed amount of ideal gas goes through an isothermal expansion

- 1) no heat enters or leaves the gas
 - 2) the gas does no work
 - 3) its internal (thermal) energy does not change
 - 4) its temperature must decrease
 - 5) its pressure must increase.
3. A thermally isolated system is made up of a hot piece of aluminum and a cold piece of copper, the aluminum and the copper are in thermal contact. The specific heat of aluminum is more than double that of copper. Which object experiences the greater temperature change during the time the system takes to reach thermal equilibrium?
- 1) The copper experiences a greater temperature change
 - 2) The aluminum experiences a greater temperature change
 - 3) Neither, both objects experience the same magnitude temperature change
 - 4) It is impossible to tell without knowing the masses
 - 5) It is impossible to tell without knowing the volumes

[Turn Over]

- 4 Two identical small charged spheres are a certain distance apart, and each one initially experiences an electrostatic force of magnitude F due to the other. With time, charge gradually leaks off of both spheres. When each of the spheres has lost half its initial charge, the magnitude of the electrostatic force will be
- 1) $1/16F$
 - 2) $1/8F$
 - 3) $1/4F$
 - 4) $1/2F$
 - 5) $1/36F$.
- 5 A positive point charge Q is fixed on a very large horizontal frictionless tabletop. A second positive point charge q is released from rest near the stationary charge and is free to move. Which statement best describes the motion of q after it is released?
- 1) Its speed will be greatest just after it is released
 - 2) Its acceleration is zero just after it is released
 - 3) As it moves farther and farther from Q , its acceleration will keep increasing
 - 4) As it moves farther and farther from Q , its speed will decrease
 - 5) As it moves farther and farther from Q , its speed will keep increasing
- 6 When two point charges are a distance d apart, the electric force that each one feels from the other has magnitude F . In order to make this force twice as strong, the distance would have to be changed to
- 1) $2d$
 - 2) $\sqrt{2}d$
 - 3) $d/\sqrt{2}$
 - 4) $d/2$
 - 5) $d/4$

[Turn Over]

- 7 Which of the following statements about Gauss's law are correct?
- 1) Gauss's law is valid only for symmetric charge distributions, such as spheres and cylinders
 - 2) If there is no charge inside of a Gaussian surface, the electric field must be zero at points of that surface
 - 3) Only charge enclosed within a Gaussian surface can produce an electric field at points on that surface
 - 4) If a Gaussian surface is completely inside an electrostatic conductor, the electric field must always be zero at all points on that surface. The electric flux passing through a Gaussian surface depends only on the amount of charge inside that surface, not on its size or shape
 - 5) All the options are correct.
- 8 A cylindrical wire has a resistance R and resistivity ρ . If its length and diameter are both cut in half, what will be its resistance and resistivity?
- 1) $4R, \rho/4$
 - 2) $2R, \rho$
 - 3) $4R, \rho$
 - 4) $R/2, \rho/2$
 - 5) $R/4, \rho/4$

[Turn Over]

- 9 An RC circuit is connected across an ideal DC voltage source through an open switch. The switch is closed at time $t = 0$ s. Which of the following statements regarding the circuit are correct?
- 1) The capacitor charges to its maximum value in one time constant and the current is zero at that time.
 - 2) The potential difference across the resistor and the potential difference across the capacitor are always equal.
 - 3) The potential difference across the resistor is always greater than the potential difference across the capacitor.
 - 4) The potential difference across the capacitor is always greater than the potential difference across the resistor.
 - 5) Once the capacitor is essentially fully charged, there is no appreciable current in the circuit.
- 10 Three resistors $R_1 = 4\Omega$, $R_2 = 8\Omega$ and $R_3 = 24\Omega$ are to be connected together. To minimize the total resistance of the circuit,
- 1) all the resistors must be connected in series,
 - 2) R_1 and R_3 must be connected in parallel,
 - 3) R_2 and R_3 must be connected in series,
 - 4) all the resistors must be connected in parallel,
 - 5) R_1 and R_2 must be connected in series.

[Turn Over]

SECTION B (Written Solutions)

1. Mr Masango is a resident in Johannesburg. His house contains the following electrical appliances

- 1 Stove, with indications $80\ \Omega$, 5A
- 1 Geyser, with indications $120\ \Omega$, 8A
- 1 Heater, with indications $40\ \Omega$, 3A
- 1 plasma TV, with indications $10\ \Omega$, 1.6A
- 10 lamps, with indications $1.4\ \Omega$, 0.8A each

All these appliances are connected in series. Suppose you are an ESKOM employee whose duty is to collect the electricity meter data. Once at Masango's house, you are told that exactly from the beginning of the month, the meter stopped reading. However, Masango being a honest man, he provides you with the following accurate information:

- his stove is used 3 hours daily,
 - due to the winter season, both the geyser and heater are on for 2 hours daily,
 - Masango is not a TV fan, and only watches the SABC1 news for 30 minutes a day,
 - the lamps are on the whole night (10 hours, say)
- (a) Given this information, find the quantity of energy Mr Masango consumes monthly (take 1 month = 30 days) (5)
- (b) What should his electricity bill be, if 1kwh costs R1.6? (5)
- (c) In summer, Masango does not use both his heater and geyser, how much money is he saving as a result? (4)

[14]

[Turn Over]

2 A RLC circuit has voltage supplied to it at a frequency of 13.0KHz with a phase difference between the current and the voltage of magnitude 0.2rad. If the circuit has a capacitance of $5\mu\text{F}$ and an inductance of 0.050H, and the three elements are connected in series, find

- (a) The inductive reactance (X_L) (3)
- (b) The capacitive reactance (X_C) (3)
- (c) The resistance of the circuit (R) (4)
- (d) If the rms current in the circuit is $I_{\text{rms}} = 0.20\text{A}$, calculate the rms voltage across each element of the circuit (4)

[14]

3 A 10cm-wide, zero resistance slide wire is pushed towards a 2Ω resistor at a steady speed of 0.5m/s. The magnetic field strength is 0.5T.

- (a) How big is the pushing force? (4)
- (b) How much power does the pushing force supply to the wire? (4)
- (c) What are the direction and magnitude of the induced current? (3)
- (d) How much power is dissipated in the resistor? (3)

[14]

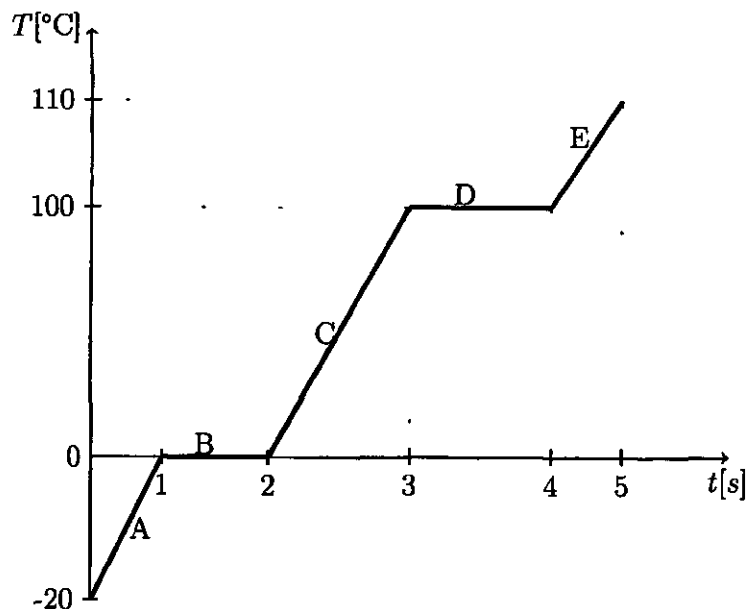
4 Explain the following thermodynamic processes.

- (a) Isochoric (4)
- (b) Isobaric (4)
- (c) Isothermal (3)
- (d) latent heat of vaporisation (3)

[14]

[Turn Over]

- 5 A 5.0g ice cube at -20°C is in a rigid, sealed container from which all the air has been evacuated. This ice is heated until it is transformed into steam at 110°C , as shown in the figure,



- (a) Explain why for phases B and D, heat is received but the temperature doesn't rise, (5)
- (b) Calculate the quantity of heat for
- i phase A (1)
 - ii phase B (1)
 - iii phase C (1)
 - iv phase D (1)
 - v phase E (1)
- (c) What is the quantity of heat required for the whole process? (4)

[14]

[Turn Over]

CONSTANTS

Latent heat of fusion of water = $3.33 \times 10^5 \text{ J/kg}$
Latent heat of vaporisation of water = $22.6 \times 10^5 \text{ J/kg}$
Specific heat capacity of water = $4186 \text{ J/kg}^\circ\text{C}$
Specific heat capacity of ice = $2090 \text{ J/kg}^\circ\text{C}$

$$\begin{aligned}\mu_0 &= 4\pi \times 10^{-7} \text{ Tm/A} \\ e &= 1.6 \times 10^{-19} \text{ C} \\ k_B &= 1.38 \times 10^{-23} \text{ J/K} \\ R &= 8.31 \text{ J/molK} \\ N_A &= 6.02 \times 10^{23} \text{ mol}^{-1} \\ \kappa &= 9.0 \times 10^9 \text{ Nm}^2\text{C}^2\end{aligned}$$

FORMULAE

$$\begin{aligned}Q &= mC\Delta t \\ Q_f &= mL_f \\ Q_{\text{elec}} &= P \times t \\ PV &= nRT, \quad R = \frac{\rho L}{A} \\ B &= \frac{\mu_0 I}{2\pi d} \\ F &= evB \\ P &= I^2 R \\ U &= IR \\ B_{\text{solenoid}} &= \frac{\mu_0 NI}{l} \\ F &= qvB \sin \alpha \\ F_{\text{mag}} &= IlB, \quad \vec{\Phi} = \vec{A} \vec{B}, \quad \xi = \frac{d\Phi}{dt}, \quad E_{\text{elec}} = \kappa \frac{q}{r^2}\end{aligned}$$

PART 1 (GENERAL/ALGEMEEN) DEEL 1

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INITIALS AND SURNAME
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For use by examination invigilator
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- IMPORTANT**
- 1 USE ONLY AN HB PENCIL TO COMPLETE THIS SHEET
 - 2 MARK LIKE THIS 
 - 3 CHECK THAT YOUR INITIALS AND SURNAME HAS BEEN FILLED IN CORRECTLY
 - 4 ENTER YOUR STUDENT NUMBER FROM LEFT TO RIGHT
 - 5 CHECK THAT YOUR STUDENT NUMBER HAS BEEN FILLED IN CORRECTLY
 - 6 CHECK THAT THE UNIQUE NUMBER HAS BEEN FILLED IN CORRECTLY
 - 7 CHECK THAT ONLY ONE ANSWER PER QUESTION HAS BEEN MARKED
 - 8 DO NOT FOLD

- BELANGRIK**
- 1 GEBRUIK SLEGS N HB POTLOOD OM HIERDIE BLAD TE VOLTOOI
 - 2 MERK AS VOLG 
 - 3 KONTROLEER DAT U VOORLETTERS EN VAN REG INGEVUL IS
 - 4 VUL U STUDENTENOMMER VAN LINKS NA REGS IN
 - 5 KONTROLEER DAT U DIE KORREKTE STUDENTENOMMER VERSTREK HET
 - 6 KONTROLEER DAT DIE UNIEKE NOMMER REG INGEVUL IS
 - 7 MAAK SEKER DAT NET EEN ALTERNATIEF PER VRAAG GEMERK IS
 - 8 MOENIE VOU NIE

PART 2 (ANSWERS/ANTWOORDE) DEEL 2

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Specimen only