'समानो मन्त्रः समितिः समानी'

# UNIVERSITY OF NORTH BENGAL

B.Sc. Honours Part-II Examination, 2022

## PHYSICS

## PAPER-V

Time Allotted: 4 Hours | Full Marks: 70

*The figures in the margin indicate full marks.*
*All symbols are of usual significance.*

**Answer Question No. 1 and *five* from the rest, taking at least *one* from each group.**

1. (a) Define temperature for a thermodynamic system. 2

   (b) A wire is shaped into a regular hexagon of side '$a$'. What is the magnetic field $(\vec{B})$ at the center of the hexagon if a steady current '$i$' flows through the wire? 3

   (c) Prove that $\left(\frac{\partial P}{\partial V}\right)_T\left(\frac{\partial V}{\partial T}\right)_P = -\left(\frac{\partial P}{\partial T}\right)_V$ and $\left(\frac{\partial P}{\partial V}\right)_T = \left(\frac{\partial V}{\partial P}\right)_T$. $1\frac{1}{2}+1\frac{1}{2}$

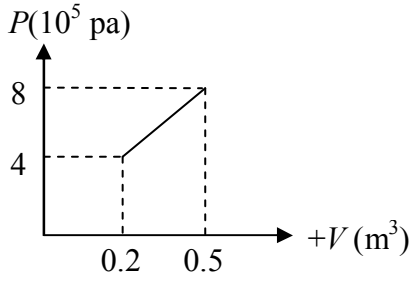
   (d) Show that $\vec{\nabla}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$ and explain the significance of the relation. 2

### GROUP-A

### (Thermodynamics)

2. (a) What do you mean by internal energy $(U)$ of a system? Prove the relation $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right) - P$, where the symbols have their usual meaning. 2+2

   (b) Upon expansion, the pressure of an ideal gas rose linearly as shown, 2+2




   What work did the gas perform? What quantity of heat has been applied?

   (c) Show that for an adiabatic charge in a perfect gas $PV^\gamma$ = const, where $\gamma$ is the ratio of the specific heats at constant pressure and constant volume respectively. 4

3. (a) Calculate the thermal efficiency of Carnot's engine. 4

   (b) Two identical bodies are kept at temperature $T_1$ and $T_2$, and are allowed to mix. They finally attain an equilibrium temperature $T$. Show that, $T = \sqrt{T_1 T_2}$ and the work done is $W = C(\sqrt{T_1} - \sqrt{T_2})^2$, where '$C$' is the heat capacity of two bodies. 5

   (c) Why absolute entropy cannot be defined for a thermodynamic system? Discuss the physical significance of entropy in terms of thermal equilibrium. 1+2

4. (a) What do you mean by Helmholtz free energy ($F$) of a system? Show that it is related to the internal energy ($U$) of the system as $U = -T^2\left[\frac{\partial}{\partial T}(F/T)\right]$. 1+3

   (b) Prove that $\frac{E_S}{E_T} = \gamma$, where symbols have their usual meaning. 2

   (c) Prove that $\left(\frac{\partial C_P}{\partial P}\right)_T = -T\left(\frac{\partial^2 V}{\partial T^2}\right)_P$. 2

   (d) What is Joule-Thompson coefficient? Show that for one mole real Van der Waal gas it is given by $\frac{1}{C_P}\left(\frac{2a}{RT} - b\right)$, where the symbols have their usual meaning. 4

5. (a) What is the difference between first-order and second-order phase transition? 2

   (b) Show that $\frac{dL}{dT} = \frac{L}{T} + Cf - Ci$, where symbols have their usual meaning. 3

   (c) What is Gibb's phase rule? Explain its physical significance. Calculate the degrees of freedom for water ($H_2O$) at triple point. 3+1

   (d) State and explain Nernst heat theorem. 3

## GROUP-B

## (Electricity-II)

6. (a) State Ampere's circuital law and show that it is independent of the shape of the chosen path. 1+2

   (b) A current $I$ passes through a straight conductor of length $(l = \pi r)$. The magnetic induction at a perpendicular distance '$r$' from the center of the wire is $B_1$. The same conductor is now bent in the form of a semi-circular arc of the same radius $r$, the magnetic induction at the same point is now $B_2$. Find the relation between $B_1$ and $B_2$. 5

   (c) What is series resonance in an electric circuit? What are the resonant frequency, bandwidth and $Q$-factor of this circuit? 1+1+1+1

7. (a) What do you mean by magnetic vector potential? Find the magnetic vector potential of an infinite solenoid with '$n$' turns per unit length, radius $r$ and carrying a steady current $I$. 1+3

(b) A circuit has an inductance of 10 mH, a capacitance of 0.1 μF and a resistance of 1 kΩ, all connected in a series circuit. Is the circuit oscillatory? — Explain. 3

(c) In a material, the magnetization is $\vec{M} = (2z\hat{i} - 3x\hat{j})$ A/m. Find the bound current density. 3

(d) The charge on a lossless capacitor of 1 μF falls to 50% of its initial value in 5 mins, when the two plates of the capacitor are joined by an unknown resistance. What is the value of the resistance? 2

8. (a) A circuit consisting of a capacitor 2 μF and a resistor 1 kΩ. An alternating emf of r.m.s. value 12 V and frequency 50 Hz is applied. Find the current flowing in the circuit and the average power supplied. 3

(b) What do you mean by Hysteresis? Indicate how a sample of steel and that of a soft iron piece differ in their magnetic behaviour? 1+2

(c) Establish Faraday's law of electromagnetic induction when a conducting loop moves with a velocity $\vec{v}$ in a non-uniform magnetic field. 4

(d) Why is capacitance used in an AC bridge for measurement of inductances? 2

9. (a) What do you mean by self inductance and mutual inductance? Self inductance of two coils are $L_1$ and $L_2$ respectively and their mutual inductance is *M*. Show from energy consideration that in general $M^2 \leq L_1 L_2$. 2+3

(b) How are non-inductive coils prepared? Discuss the principle underlying it. 3

(c) Two refrigerators are supplied from the same a.c. source, the first one draws a current of 3A at a power factor of 0.6 and the second one draws a current of 2A at a power factor of 0.7. Assuming that the current lags behind the emf in both the cases, calculate the total current drawn by the two refrigerators and the corresponding power factors. 4

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