3 (Sem–3/CBCS) PHY HC 1

2023

PHYSICS

(Honours Core)

Paper : PHY–HC–3016

(Mathematical Physics–II)

Full Marks : 60

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : $1\times7=7$

   (a) Define the ordinary point of a second order differential equation.

   (b) Show that $P_0(x)=1$.

   (c) Write the Laplace equation in spherical polar co-ordinate system.

   (d) A partial differential equation has

   (i) one independent variable

(ii) more than one dependent variable

(iii) two or more independent variables

(iv) no independent variable.

(Choose the correct option)

(e) If A and B are two square matrices of order n, show that

$$Trace\,(A+B) = Trace\,A + Trace\,B$$

(f) Which one of the following is the value of $\Gamma\left(\frac{1}{2}\right)$?

(i) $\sqrt{\pi/2}$

(ii) $\sqrt{\pi}$

(iii) π

(iv) $\sqrt{\pi}/2$

(g) Define self adjoint of a matrix.

2. Answer the following questions : 2×4=8

(a) Check the behaviour of point $x=0$ for the differential equation

$$\frac{d^2y}{dx^2} - \frac{6}{x}y = 0$$

(b) If $\int_{-1}^{+1} P_n(x)\,dx = 2$, find the value of n.

(c) Express the Fourier series in complex form.

(d) Verify the matrix

$$A = \begin{bmatrix} \cos\theta & i\sin\theta \\ i\sin\theta & \cos\theta \end{bmatrix}$$ is a unitary matrix.

3. Answer ***any three*** of the following questions : 5×3=15

(a) Find the power series solution of the following differential equation :

$$\left(1-x^2\right)\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2y = 0$$

about $x=0$.

(b) Define Gamma function. Show that

$$\int_0^{\infty} e^{-x^2}\,dx = \frac{\sqrt{\pi}}{2}$$ 1+4=5

(c) Establish the following recurrence formula for Legendre polynomial $P_n(x)$

$$nP_n(x) = (2n-1)xP_{n-1}(x) - (n-1)P_{n-2}(x)$$

(d) Show that the Fourier expansion of the function $f(x) = x$, $0 < x < 2\pi$ is

$$x = \pi - 2\left[\sin x + \frac{1}{2}\sin 2x + \frac{1}{3}\sin 3x + \ldots.\right]$$

(e) What is eigenvalue of a matrix? Show that the eigenvalues of Hermitian matrix are real. 1+4=5

4. Answer ***any three*** of the following questions : 10×3=30

(a) (i) If $P_n(x)$ be the polynomial of Legendre's differential equation, show that

$$P_n(x) = \frac{1}{2^n.n!} \cdot \frac{d^n}{dx^n}\left(x^2-1\right)^n$$ 6

(ii) Prove that 4

$$\int_{-1}^{+1} xP_n(x)P_{n-1}(x)\,dx = \frac{2n}{4n^2-1}$$

(b) (i) What is Beta function ? Show that

(a) $\beta(1,1) = 1$

(b) $\beta(m,n) = \beta(n,m)$ 1+1+3=5

(ii) If $A = \begin{bmatrix} 1 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{bmatrix}$, show that

$A^2 - 4A - 5I = 0$ where I and 0 are the unit matrix and the null matrix of order 3 respectively. Also use this result to find A^{-1}. 3+2=5

(c) Find the Fourier series expansion of

$$f(x) = \begin{cases} -\pi, & -\pi < x < 0 \\ x, & 0 < x < \pi \end{cases}$$

Also show that

$$\frac{\pi^2}{8} = \frac{1}{1^2} + \frac{1}{3^2} + \frac{1}{5^2} + \cdots$$ 6+4=10

(d) (i) Diagonalize the following matrix

$$A = \begin{bmatrix} 1 & 0 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \end{bmatrix}$$ 5

(ii) Show that the generating function for Hermite polynomial $H_n(x)$, for integral n and real value of n is given by

$$e^{2xt-t^2} = \sum_{n=0}^{\infty} \frac{t^n}{n!} H_n(x) \qquad 5$$

(e) (i) Write the one dimensional diffusion equation (heat flow equation) and find the general solution of the same by the method of separation of variable.

1+7=8

(ii) For the Pauli spin matrices

$$\sigma_1 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}, \quad \sigma_2 = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} \text{ and}$$

$$\sigma_3 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \text{ show that}$$

$$[\sigma_1, \sigma_2] = 2i\sigma_3 \qquad 2$$

(f) (i) Write the Orthogonality conditions of *sine* and *cosine* functions.

1½+1½=3

(ii) A square wave function is represented as

$$f(x) = \begin{cases} 0, & \text{for } -\pi < x < 0 \\ h, & \text{for } 0 \le x < \pi \end{cases}$$

Draw the graphical representation of the wave function and expand the same in Fourier series.

1+6=7

---

3 (Sem–3/CBCS) PHY HC 2

2023

PHYSICS

(Honours Core)

Paper : PHY–HC–3026

(Thermal Physics)

Full Marks : 60

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×7=7

   (a) What are intensive thermodynamic variables ?

   (b) Write the differential form of 1st law of thermodynamics.

   (c) What is the change in internal energy of a system over one complete cycle ?

   (d) Why the workdone in isochoric process is zero ?

   (e) State 3rd law of thermodynamics.

(f) Name the transport phenomenon present in gas that involves transfer of mass.

(g) How does mean free path of gas molecule change when temperature and pressure are doubled?

2. Answer the following questions : 2×4=8

(a) 'Work and heat are equivalent to each other' – Explain.

(b) Why efficiency of a Carnot engine cannot be 100%?

(c) Find the change in entropy when 10 *gm* of ice at 0 °C is converted into water at the same temperature.

(d) If critical temperature of a gas is 300*K*, find its temperature of inversion.

3. Answer ***any three*** of the following : 5×3=15

(a) Derive an expression of work done in adiabatic process.

(b) Derive the expression of change in entropy of a perfect gas when its state changes from (T_1, P_1) to (T_2, P_2).

(c) Using laws of thermodynamics derive Maxwell's first thermodynamic relation.

(d) State law of equipartion of energy using this law find the expression of ratio between two specific heat of a gas in terms of degree of freedom. 1+4=5

(e) The molecular diameter of a gas molecule is $10^{-8}cm$. Calculate the mean free path at temperature 27 °C and at pressure $10^5 dyne/cm^2$. [Boltzmann constant, $k=1{\cdot}4\times10^{-16}erg/K$]

4. Answer ***any three*** of the following : 10×3=30

(a) What is heat engine? Is Carnot engine a heat engine? Describe the four processes involved in a Carnot engine and hence derive the efficiency of the engine. 1+1+8=10

(b) Derive Clausius-Clapeyron equation from Maxwell's thermodynamic relation. Using this law explain the effect of pressure *(i)* on boiling point of liquid *(ii)* on melting point of solid. 6+2+2=10

(c) Derive the expression of average speed, r.m.s speed and most probable speed of gas molecules using Maxwell's velocity distribution law and hence find their ratio. 3+3+3+1=10

(d) Derive the relation, $\eta = \frac{1}{3}\rho \bar{c} \lambda$, where

$\eta \rightarrow$ coefficient of viscosity

$\rho \rightarrow$ density

$\bar{c} \rightarrow$ average velocity

$\lambda \rightarrow$ mean free path

(e) What is equation of state? Write the ideal gas equation. Explain the two correction introduced in ideal gas equation to derive van der Waals equation of state. On what factors do the van der Waals constant a and b depend? 1+1+6+2=10

(f) Write short notes on ***any two*** of the following: 5+5=10

(i) Reversible and irreversible process

(ii) Refrigerator and coefficient of performance

(iii) Gibbs potential

(iv) Joule-Thomson cooling

———

3 (Sem–3/CBCS) PHY HC 3

2023

PHYSICS

(Honours Core)

Paper : PHY–HC–3036

(Digital Systems and Applications)

Full Marks : 60

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×7=7

(a) What is the function of the trigger circuit in a CRO ?

(A) To control the vertical deflection.

(B) To adjust the horizontal position of the trace.

(C) To stabilize the waveform display.

(D) To change the time/division setting.

(b) Which of the following statement is not true ?

(A) Analog ICs are more suitable for applications that involve precise control of voltage and current.

(B) A flip-flop is a component of digital IC commonly used for data storage and sequential logic operations.

(C) Digital ICs are typically more resistant to noise and interference compared to analog ICs.

(D) Operational amplifiers (op-amps) are commonly found in digital ICs for performing arithmetic and logic operations.

(c) What is the BCD representation of the decimal number 7 ?

(d) In a 3-variable Boolean expression, how many Minterms, and Maxterms can be obtained ?

(e) What are the *two* outputs produced by a half adder ?

(f) How many operational modes does the IC555 timer have ?

(g) What is the size of the data bus in the 8085 microprocessors ?

2. Give answer to the following questions : 2×4=8

(a) What do you mean by deflection sensitivity of a CRO ?

(b) Mention *two* differences between active and passive components of an IC.

(c) Draw the external circuit diagram of an IC555 used as an astable multivibrator.

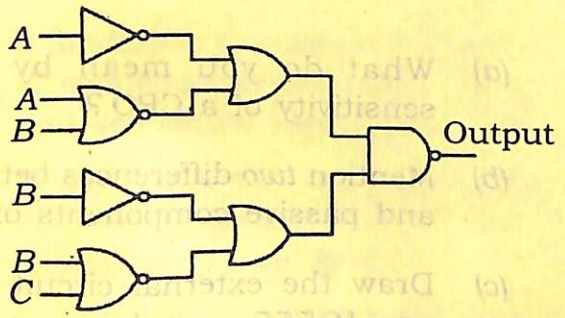
(d) Draw the logic diagram of a 4-bit parallel-in-serial-out shift register.

3. Answer ***any three*** questions from the following : 5×3=15

(a) Mention the names of the logic gates known as Universal gate. Describe how AND gate and OR gate can be realised using *any one* of the Universal gates. 1+2+2=5

(b) Describe the working of NAND gate using Transistor logic.

(c) Draw the simplest possible logic diagram to provide the output of the following logic diagram :



(d) What do you mean by 'minterm' in a Boolean expression? Expand the following Boolean expression into minterms : 1+4=5

$$A + B\overline{C} + AB\overline{D} + ABCD$$

(e) Draw the circuit diagram of a 1 to 4 demultiplexer and give its truth table. Mention *two* applications of demultiplexer. 3+2=5

4. Answer ***any three*** questions from the following : 10×3=30

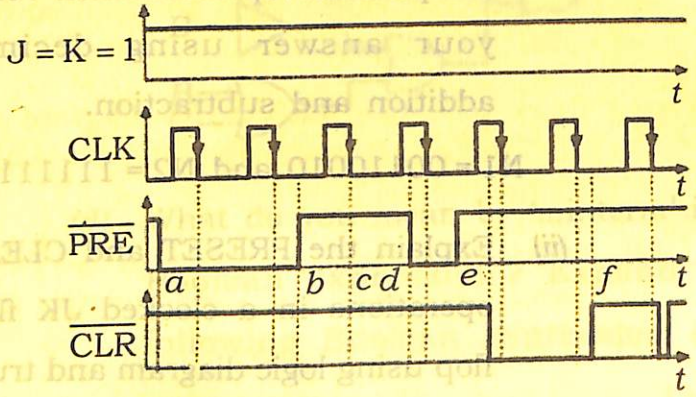
(a) (i) Perform the addition and subtraction of the following 8-bit numbers expressed in 2's complement representation. Verify your answer using decimal addition and subtraction. 4

N1 = 00110010 and N2 = 11111101

(ii) Explain the PRESET and CLEAR operations in a clocked JK flip-flop using logic diagram and truth table. 6

(b) (i) Describe the basic components of a 4-bit binary adder circuit. How does it handle the addition of two binary numbers, including carry propagation? 4

(ii) The waveforms shown in the following figure are applied to a NGT clocked JK flip-flop having active low Preset and Clear inputs. Draw the output waveform explaining its behaviour at the indicated time steps (*a*, *b*, *c*, *d*, *e*, *f*). Consider the flip-flop is initially at RESET condition. 6



(c) (i) Mention *two* basic differences between synchronous and asynchronous counters. Draw the logic diagram of a decade counter. 2+3=5

(ii) What do you mean by the modulus of a counter? Design a three-bit asynchronous up counter using negative edge triggered flip-flops. 1+4=5

(d) (i) Discuss various levels of memory used in computer system and their characteristics. 5

(ii) Give *two* examples of output device of a computer system. What do you mean by the term 'bus' in computer? Discuss about the two types of buses used in CPU of a computer. 1+1+3=5

(e) (i) What do you mean by flag registers? Describe briefly the function of various flag registers. 1+5=6

Or

With neat diagram explain the working of various buses in a microprocessor based system. 6

(ii) Differentiate between the 2-byte instructions and 3-byte instruction code in case of 8085 microprocessor. Write an Assembly Language Program to transfer data from register *B* to *C*. 2+2=4

Or

Write an 8085 Assembly Language Program to add two 8-bit hexadecimal numbers stored in memory using direct addressing mode. 4

(f) (i) Write *two* differences between Analog and Digital circuits. 2

(ii) Using truth tables, prove the following : 6

1. $\overline{A.B} = \overline{A} + \overline{B}$

2. $\overline{A+B} = \overline{A}.\overline{B}$

(iii) Mention the truth table of XNOR gate. 2