WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2022-23

PHSACOR05T-PHYSICS (CC5)

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) Let $F(x)$ have a Fourier Series expansion

$$F(x)=\sum_{n=1}(a_n\cos nx+b_n\sin nx)$$

then prove that, $\langle F^2(x)\rangle=\frac{1}{2\pi}\int_{-\pi}^{\pi}F^2(x)dx=\sum_{n=1}^{\infty}\begin{pmatrix}a_n^2+b_n^2\\2\end{pmatrix}$

(b) Can $y=\tan x$ be expanded in a Fourier Series? Explain.

(c) Verify whether $y_1(x)=\sin\sqrt{x}$ and $y_2(x)=\cos\sqrt{x}$ are linearly independent or not.

(d) From the generating function $G(z,h)=(1-2zh+h^2)^{-1/2}=\sum_{n=0}P_n(z)h^n$, determine $P_3(z)$.

(e) Prove that $J_{n+1}(x)+J_{n-1}(x)=\frac{2n}{}J_n(x)$.

(f) Prove that $J_{1/2}(x)=\sqrt{\frac{2}{\pi x}}\sin x$.

(g) Express $f(x)=6x^2+7x+2$ in terms of Legendre polynomials.

(h) Write down the orthogonality properties of Hermite polynomial.

(i) Evaluate $\Gamma\left(\frac{5}{2}\right)$ using $\Gamma\left(\frac{1}{2}\right)=\sqrt{\pi}$.

(j) Lagrangian of a point mass (m) under gravity (g) is given by

$$L=\frac{1}{2}m(\dot{x}^2+\dot{y}^2+\dot{z}^2)-mgh$$

What are the cyclic coordinates for the system?

(k) Show that the general solution of the wave equation

$\frac{\partial^2 y}{\partial t^2}=c^2\frac{\partial^2 y}{\partial x^2}$ is of the form $y=f_1(x-ct)+f_2(x+ct)$.

(l) Find the Hamiltonian for a particle moving in a rotating frame.

(m) State Hamilton's principle.

(n) Prove that

(i) $[F,G]=-[G,F]$ and

(ii) $[cF,G]=c[F,G]$ where c = constant. and [ ] = Poisson bracket.

2. (a) Expand as a Fourier Series

$$f(x) = x^2 + x \text{ for } -\pi \le x \le \pi$$

(b) Prove that $\beta(m, n) = \dfrac{\Gamma(m)\Gamma(n)}{\Gamma(m+n)}$ and find the value of $\beta\left(\frac{3}{2}, \frac{1}{2}\right)$. 3+1

(c) Show that $P_n(-x) = (-1)^n P_n(x)$ 2

3. (a) Using the generating function for the Hermite polynomial $H_n(x)$ expressed as 2+2

$$e^{2tx-t^2} = \sum_{n=0}^{\infty} \frac{1}{n!} t^n H_n(x)$$

Solve the following recurrence relation

(i) $2nH_{n-1}(x) = H_n'(x)$

(ii) $2xH_n(x) = 2nH_{n-1}(x) + H_{n+1}(x)$

(b) For the Legendre polynomials, show that 3

$$P_{2n}(0) = (-1)^n \frac{(2n-1)!!}{(2n)!!}$$

(c) Consider an electric charge q placed on the z-axis at $z = a$. Show that the electric potential at a non-axial point having position vector $\vec{r}$ is given by 3

$$V = \frac{q}{4\pi\varepsilon_0 r} \sum_{n=0}^{\infty} P_n(\cos\theta)\left(\frac{a}{r}\right)^n$$

Where $P_n(\cos\theta)$ are Legendre Polynomials.

4. (a) Using Hamilton's Canonical equations, derive the equation of motion of a particle moving in a force field in which the potential is given by $V = -\dfrac{k}{r}$, where k is positive constant. 4

(b) Given the Lagrangian $L = \dfrac{1}{2}m(\dot{r}^2 + r^2\dot{\theta}^2) - V(r)$. Find the Hamiltonian and hence the equations of motion. 3

(c) Prove that $(n+1)P_{n+1} = (2n+1)x P_n - nP_{n-1}$. 3

5. (a) Solve the differential equation 3

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} \text{ if } u(x, 0) = \sin \pi x.$$

(b) An electric dipole with opposite charges of masses m_1 and m_2 separated by a distance l is placed in an external homogeneous electric field. Write down the Lagrangian of the dipole. 3

(c) Apply Legendre Transformation on the Internal energy function $U = U(S, V)$ to obtain Helmholtz free energy $F = F(T, V)$. 2

(d) If ψ is a solution of Laplace's equation, show that $\dfrac{\partial \psi}{\partial z}$ is also a solution. 2

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2022-23

PHSACOR06T-PHYSICS (CC6)

Time Allotted: 2 Hours | Full Marks: 40

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Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and any *two* questions from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) At what temperature the molecular velocity (r.m.s.) of oxygen will become half as that of hydrogen?

[Molecular weight of oxygen and hydrogen are 32 and 2 respectively]

(b) Calculate the total random kinetic energy of one gm-mole of O_2 at 300 K.

(c) Calculate the number of collisions per second of a molecule of gas having mean free path 2×10^7 m. Given the average velocity 500 m/sec.

(d) What is Boyle's temperature? Find Boyle's temperature for Van der Waal's gas.

(e) What do you mean by critical temperature of a gas? What is its importance?

(f) What is degree of freedom? State the law of equipartition of energy.

(g) Show that the workdone in adiabatic expansion of an ideal gas from a state (P_1, V_1) to a state (P_2, V_2) is given by $W = \frac{1}{(\gamma-1)}[P_1V_1 - P_2V_2]$.

(h) A Carnot's engine has an efficiency of 30% when the temperature of the sink is 27°C. What must be the change in temperature of the source to make its efficiency 50%.

(i) Prove that in a T-S diagram the slope of isochoric curve is T/C_V.

(j) What is the physical significance of entropy?

(k) Why are the Helmholtz function F and Gibbs' function G called thermodynamic potentials? Explain.

(l) State the Gibbs' phase rule. Draw the P-T diagram of water indicating the triple point.

(m) Using Maxwell's relation prove that $\left(\frac{\partial u}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$

(n) Show that the Joule-Thomson co-efficient is zero for ideal gas.

2. (a) Write down Maxwell's molecular speed distribution law and explain the symbols you use. 2

(b) Indicate graphically how the distribution changes with rise of temperature and pressure.

(c) Starting from speed distribution law of Maxwell, deduce the energy distribution law of the molecules of a gas. Draw energy distribution curves at different temperatures. 2+1

(d) What importance was obtained from Andrew's experiment? 2

3. (a) Represent a Carnot's cycle on a T-S diagram and hence find the efficiency of a Carnot's engine. 1+3

(b) Show that no engine between two given temperatures can be more efficient than a reversible Carnot's engine working between the same two temperatures. 3

(c) Calculate the change in entropy when 10 gm of ice at –10°C is converted into water at 10°C. 3

4. (a) Show that Joule-Thomson effect is an isenthalpic. 2

(b) Compare Joule-Thomson effect and adiabatic temperature. 2

(c) What is inversion temperature? Find its expression for Van der Waal's gas. 2+4

5. (a) Prove that $C_P - C_V = T\left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial V}{\partial T}\right)_P$, where the symbols have their usual meaning. 3

(b) Using Maxwell's thermodynamic relation establish the Clausius-Clapeyron equation 4

$$\left(\frac{\partial P}{\partial T}\right) = \frac{L}{T(V_2 - V_1)}$$

(c) Calculate the change in boiling point of water when the pressure is increased by 1 atmosphere. Boiling point of water is 100°C, specific volume of steam is 1.671 m^3/kg and latent heat of steam 2.268×10^6 J/kg 3

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2022-23

PHSACOR07T-PHYSICS (CC7)

Time Allotted: 2 Hours | Full Marks: 40

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All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

   (a) How can the phase difference between two AC voltages be measured by CRO?

   (b) Differentiate between clipping and clamping circuits.

   (c) What are the disadvantages of an S-R flip-flop?

   (d) What is MOD-5 counter? What are the main functions of a register?

   (e) Mention the advantage of MS-flip flop over JK flip-flop.

   (f) Why combinational circuit is faster than sequential circuits?

   (g) Draw the circuit diagram of NOT gate using transistor.

   (h) What is ripple counter and parallel counter?

   (i) Find the base n if $7_n \times 8_n = 38_n$.

   (j) What do you mean by the passive component of an electronic circuit?

   (k) Write down the truth table of a 2-input Ex-OR gate, why is it called a coincidence checker?

   (l) What is meant by race-around condition in a flip-flop? How can it be avoided?

   (m) Write the output of a comparator circuit.

   (n) Draw a neat block diagram for a 4-bits ripple counter with S-R flip-flops.

   (o) What is triggering? Write down the types of triggering.

2. (a) How the JK Flip-Flop can be used as the T Flip-Flop? Write its truth table. 2+1

   (b) Draw the logic diagram of 1-to-4 demultiplexer. How many select input is required for 1-to-16 demultiplexer? 3+1

   (c) Draw the circuit diagram of decade synchronous counter using JK flip-flop. 3

3. (a) What is a data register? Draw a 4-bit parallel in and parallel out shift register using D flip-flops. 1+3

   (b) Design a two input XOR gate using NOR gates only. 3

(c) A 12 MHz square wave clocks a 6 bit ripple counter. What is the frequency of th last flip-flop?

(d) Explain the difference between ROM and RAM.

4. (a) Expand $A(\overline{A}+B)(\overline{A}+B+\overline{C})$ to maxterms and minterms. 3

(b) Design asynchronous mod-10 counter using JK flip-flop. Show the output. 3

(c) When does an XOR gate give high output? 2

(d) What is duality theorem in Boolean Algebra? Explain with an example. 2

5. (a) The calibration time base of a CRO is set at 2 ms/cm. The horizontal distance on the screen for one cycle of an a.c voltage applied to the vertical input is 2.5 cm. Find the frequency of the ac voltage. 3

(b) Draw the Logic diagram of a 4-bit Full adder circuit using full adders only. 3

(c) Write two applications of Flip-flops. 1

(d) Design an astable multivibrator using 555 timer for a frequency of 1 kHz and duty cycle of 70%. 3

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2021-22

PHSACOR05T-PHYSICS (CC5)

MATHEMATICAL PHYSICS-II

Time Allotted: 2 Hours | Full Marks: 40

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Answers must be precise and to the point to earn credit.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) How will you change the function $f(x)$ in the interval $(-\pi,\pi)$ to $(-l,l)$ in Fourier series?

(b) Sketch the periodic extension of $f(t)=0$ for $t < 0$, $f(t)=1$ for $t > 0$, if the fundamental interval is (−1, 1).

(c) Let $F(x,y,y')=2x+xy'+(y')^2+y$, then obtain the corresponding Euler Lagrange equations that follow from Hamilton's principle.

(d) Prove that if the Lagrangian of a conservative system does not contain time explicitly, the total energy is conserved.

(e) Prove that $P_{2m+1}(0)=0$.

(f) Find the nature and location of the singularities of the following differential equation $(1-x^2)y''-2xy'+l(l+1)y=0$.

(g) For integer *n* Bessel function of first kind are given as,

$$J_n(x)=\sum_{j=0}^{\infty}\frac{(-1)^j(x/2)^{2j+n}}{j!\Gamma(n+j+1)}$$

Show that $J_{-n}(x)=(-1)^n J_n(x)$.

(h) State Hamilton's principle.

(i) What do you understand by degrees of freedom of a dynamical system?

(j) Determine the Wronskian for the differential equation $y''+y=0$.

(k) If $H_n(x)$ are Hermite polynomials then evaluate $\int_{-\infty}^{\infty} H_2(x)H_3(x)e^{-hx^2}dx$.

(l) Using Generating function of $H_n(x)$ i.e. $e^{-t^2+2tx} = \sum_{n=0}^{\infty} H_n \frac{t^n}{n!}$,

show that $H_n(-x) = (-1)^n H_n(x)$

(m) With the help of Legendre transformation, determine the Hamiltonian corresponding to the Lagrangian $L = \frac{1}{m}\dot{x}^2$, where m is a constant.

(n) Consider $y = \sum_{r=0}^{\infty} a_k x^{k+m}$. Obtain the indicial equation and it's roots for the Legendre's differential equation.

2. (a) Write the differential equation obeyed by Legendre polynomials. Show that 3

$$P_n(x) = \frac{1}{2^n n!}\frac{d^n}{dx^n}(x^2-1)^n$$

(b) If $f(x) = 0$ for $0 < x < \pi/2$ 4

$= \pi - x$ for $\pi/2 < x < \pi$,

Then show that $f(x) = \frac{\pi}{4} - \frac{2}{\pi}\left(\frac{1}{1^2}\cos 2x + \frac{1}{3^2}\cos 6x + \ldots\right)$

(c) Solve the differential equation 3

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0 \text{ and obtain } \phi(x,y)$$

Given $\phi(x,y) = \phi(0,y) = 0$

3. (a) Using the generating function for the Legendre polynomials $P_n(x)$ to show that 2+2

Prove that $\int_{-1}^{1} [P_n(x)]^2 dx = \frac{2}{2n+1}$

and hence show that $\int_{-1}^{1} P_3^2(x)\,dx = \frac{2}{7}$

(b) Show that the Bessel function 3

$$J_n(x) = \sum_{j=0}^{\infty} \frac{(-1)^j (x/2)^{2j+n}}{j!\Gamma(n+j+1)}$$

satisfy the Bessel's equation $x^2y'' + xy' + (x^2 - n^2)y = 0$.

(c) Apply Legendre Transformation on the Internal energy function U(S,V) to obtain Gibbs free energy G(T,P). 3

4. (a) Consider the differential equation $2x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} - (x+1)y = 0$, obtain a series solution in powers of x using Frobenius method. 5

(b) Derive Hamilton's canonical equations of motion. Obtain Hamilton's equation for a particle in a central force field. 2+3

5. (a) A charge $+q$ is distributed uniformly along the z-axis from $z=-a$ to $z=+a$. Show that the electric potential at a point $\vec{r}$ is given by

$$V(r,\theta)=\frac{q}{4\pi\varepsilon_0 r}\left[1+\frac{1}{3}\left(\frac{a}{r}\right)^2 P_2(\cos\theta)+\cdots\ldots\right].,$$

where $P_n(\cos\theta)$ are Legendre polynomial.

(b) Using Hamilton's canonical equations of motion, show that the Hamiltonian $(H(x,p,t))$ is conserved provided $\frac{\partial H}{\partial t}=0$. 3

(c) If $u=f(r)$ and $x=r\cos\theta,\ y=r\sin\theta$, prove that 3

$$\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}=f''(r)+\frac{1}{r}f'(r).$$

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2021-22

PHSACOR06T-PHYSICS (CC6)

THERMAL PHYSICS

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and any *two* questions from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) Find the temperature at which the RMS velocity of a gas will be $^1/_4{}^{th}$ of that at zero degree Celsius.

(b) Calculate what fraction of gas molecules dies out in moving a distance of mean free path.

(c) Show that the number of molecules obeying Maxwell distribution law strike unit area per sec is given by $p/\sqrt{2\pi mkT}$.

(d) What are the corrections added to the perfect gas equation so as to get Van der Waals equation for real gas.

(e) Show that at the critical temperature the departure of Van der Waals law from ideal gas law is 62.5%.

(f) What is quasi-static process? Is this process always reversible one?

(g) Deduce the expression for the work done in the adiabatic expansion of a perfect gas in terms of temperature.

(h) Show that an isothermal curve for an ideal gas drawn on a P-V diagram is isenthalpic.

(i) "Specific heat at constant pressure is always greater than the specific heat at constant volume"— Explain.

(j) Find the efficiency of a Carnot's engine working between 127 °C and 27 °C. It absorbs 80 cal of heat. How much heat is rejected?

(k) Why are the Helmholtz function F and Gibbs function G called thermodynamic potentials?

(l) Calculate the change in entropy when 10 gram of ice at 0 °C is converted into the vapour at 100 °C.

(m) State the law of corresponding state.

(n) Derive the following TdS equation. Terms have their conventional meaning.

$$TdS = C_P dT - T\left(\frac{\partial V}{\partial T}\right)_P dP$$

2. (a) If the equation of state for a real gas is given by $P = \frac{RT}{V-b} e^{-\frac{a}{RTV}}$, obtain the virial expansion in power series of $(1/V)$. Find the second and third virial co-efficients.

   (b) Show the variation of the second virial coefficient with absolute temperature T and hence obtain the Boyle temperature. 1+1

   (c) For a thermodynamic system $U = \frac{3}{2}PV$ and $P = AT^4V$, find the Gibbs' potential G and Helmholtz function F. 2+2

3. (a) Show that the mean square displacement of a Brownian particle suspended in a liquid is directly proportional to the absolute temperature of the liquid. 4

   (b) Draw the Carnot cycle in the T-S diagram. Derive the expression for the efficiency of the Carnot engine directly from this diagram. 1+2

   (c) A reversible engine converts $^1/_6^{th}$ of heat which it absorbs at heat source into work. When the temperature of the heat sink is reduced by 82 °C, its efficiency is doubled. Calculate the temperature of the source and the sink. 3

4. (a) Draw the Maxwell's velocity distribution curve at different temperature. Discuss the shifting of the peak of the curve and also the broadening of the curve with temperature variation. 1+2

   (b) Using Maxwell thermodynamic relation establish Clausius-Clapeyron equation. 4

   (c) Show that in case of vapourization of liquid this equation reduces to $\ln P = -L/RT$ + constant. (assuming the vapour to behave as a perfect gas of one mole) 3

5. (a) Calculate the mean free path and collision frequency of hydrogen molecules at STP. Given: coefficient of viscosity = 0.00008 CGS unit, density (ρ) of hydrogen at STP = 0.00009 gm/cc. 4

   (b) For an isentropic transformation show that, 3+3

   (i) $\left(\frac{\partial V}{\partial T}\right)_S = -\frac{C_V}{C_P - C_V}\left(\frac{\partial V}{\partial T}\right)_P$ and

   (ii) $\left(\frac{\partial P}{\partial T}\right)_S = \frac{C_P}{C_P - C_V}\left(\frac{\partial P}{\partial T}\right)_V$

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2021-22

PHSACOR07T-PHYSICS (CC7)

Time Allotted: 2 Hours | Full Marks: 40

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Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) What is Monolithic IC? Write about its Fabrication.

(b) What type of screen is used in CRT and why?

(c) Magnetic deflection is desirable in CRTs for television: Explain why.

(d) Write down the Boolean function corresponding to the following standard POS notation

$$f(A, B, C) = \prod M(2, 3, 4, 7)$$

(e) What is the difference between synchronous and asynchronous counters?

(f) Draw the logic block diagram for adding two decimal numbers 7 and 12.

(g) What is duty of cycle?

(h) What is Veitch diagram?

(i) A 4-bit D/A converter produces an output of 4.5 V for an input code of 1001. Find the output for an input code of 0011.

(j) Difference between Ring counter and Decade counter. Add BCD numbers 0111 and 0101.

(k) What is JK flip-flop? How many bytes are there in a 32-bit data word?

(l) What is synchronous orbit?

(m) The input to a logic gate are A = 1100 and B = 1010. What will be the logic gate if the output is 0110?

(n) Show the logic symbol of full subtractor using half subtractor.

(o) Show the pinout diagram of serial in and parallel out shift Register.

2. (a) Minimize the following function by using Karnaugh mapping technique and realize the resulting logic circuits by using minimum number of logic gates. 3+2

$$f(A, B, C, D) = \sum m(0, 1, 2, 3, 11, 12, 14, 15)$$

(b) Introduce 2's complement method in binary subtraction process. Hence draw a 4-bit binary adder/subtractor circuit and briefly explain its operation.

3. (a) Write the truth table of Half Subtractor and draw its logic diagram.

(b) What advantage does a J-K flip-flop have over an SR flip-flop? Why the restriction of pulse width is necessary in JK flip-flop? 1+1

(c) An 12 MHz square wave clocks a 6-bit ripple counter. What is the frequency of the last flip-flop? 2

(d) How any flip-flop is required for Mod-17 counter? What is BCD counter? 1+1

4. (a) Add 54 with –22 using 2's complement method. 3

(b) Draw the logic diagram of a 4-bit ring counter. 2

(c) What do you mean by resetting of a counter? How many state do a 5-bit ripple counter have? 1+1

(d) What is a single bit Register? What is known as universal shift register? 1+2

5. (a) A sine wave is displayed on CRO screen with the calibrated time base set at 0.1 ms/div. One cycle of displayed waveform spreads over 10 divisions along the horizontal axis. Find the frequency of the waveform. 2

(b) How is a J-K flip-flop made to toggle? 2

(c) Master-slave J-K flip-flops are called pulse-triggered or level-triggered devices. — Why? 3

(d) Draw a 4-bit serial-in, serial-out shift register using J-K flip-flops and show output stages. 3

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2020, held in 2021

PHSACOR05T-PHYSICS (CC5)

MATHEMATICAL PHYSICS-II

Time Allotted: 2 Hours | Full Marks: 40

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Candidates should answer in their own words and adhere to the word limit as practicable.
Answers must be precise and to the point to earn credit.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) State Hamilton's principle.

(b) A cart with a pair of wheels having radius R connected through an axle of length l is rolling without slipping on an inclined plane with an angle of inclination θ. Determine the number of degrees of freedom.

(c) Lagrangian of a particle of mass m is $L=\frac{1}{2}m\dot{q}^2-\frac{1}{2}Kq^2-Kq\dot{q}t$, where K is a constant. Show that the particle is moving freely.

(d) What is the fundamental difference between Lagrange's equation and Hamilton's canonical equations for the same system?

(e) Suppose a second-order linear homogeneous ordinary differential equation in x has a power series solution like $\sum_{r=0}^{\infty}a_r x^{k+r}$, where k is a constant. Can it satisfy the recurrence relation $a_{r+2}(k+r+2)(k+r+1)+a_r(k+r+1)=0$ for $a_0, a_1=0$ simultaneously? Explain.

(f) "Hermite polynomials are orthogonal to each other in the range [0, 1] with weight function $\exp(-x^2)$." Is the statement true? Justify your answer.

(g) Mention orthogonality conditions required to determine the Fourier Coefficients.

(h) $J_0(x)$ and $J_1(x)$ are solutions of the Bessel differential equations of order 0 and 1 respectively. Show that J_0 and J_1 are linearly independent of each other.

(i) Let $F(x, y, y')=2x+xy'+y'^2+y$, then obtain the corresponding Euler-Lagrange equations that follow from Hamilton's principle.

(j) What is a convex function? Give an example.

(k) Apply Legendre Transformation on the Internal energy function $U=U(S,V)$ to obtain Helmholtz free energy $F=F(T,V)$.

(l) Prove that homogeneity of time for an isolated system leads to conservation of energy.

(m) Show that the generalized momenta conjugate to cyclic coordinates are conserved.

(n) Show that for Legendre polynomial $P_n(x)$ we can have $P_n(-x) = (-1)^n P_n(x)$.

2. (a) If $f(x)$ is any square-integrable function in the range $-\pi < x < \pi$ such that $\int_{-\pi}^{+\pi} [f(x)]^2 dx$ is finite, show that $\lim_{m\to\infty} a_m = 0$, $\lim_{m\to\infty} b_m = 0$ for the Fourier coefficients a_m and b_m. 3

(b) Suppose that the following differential equation refers to a problem of the 2D steady flow of heat: 5

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$$

Solve for u using separation of variables with given boundary conditions:

$u(0, y) = u(a, y) = u(x, \infty) = 0$ and $u(x, 0) = \sin\frac{\pi x}{a}$, where a is the length of the boundary in x-direction.

(c) If ψ is a solution of Laplace's equation, show that $\partial\psi/\partial z$ is also a solution. 2

3. (a) Prove that the solutions of the equation of motion for one dimensional simple harmonic oscillator are linearly independent. 3

(b) Expand the following function in a Fourier series $f(x) = \begin{cases} -\pi, & -\pi < x < 0 \\ x, & 0 < x < \pi \end{cases}$. 3+2

Hence show that $\frac{\pi^2}{8} = 1 + \frac{1}{9} + \frac{1}{25} + \frac{1}{49} + \cdots$

(c) Can we apply the method of separation of variables to solve the given equation 2

$$xy^2 \frac{\partial^2 u}{\partial x^2} + x^2 y \frac{\partial^2 u}{\partial y^2} = x + y$$

4. (a) Using the Rodrigue's formula, determine $P_3(x)$. 2

(b) Show that Legendre's equation has regular singularities at $x = -1$, 1 and ∞. 2

(c) Starting from Hamilton's principle, establish Euler-Lagrange's equation of motion for any bilateral holonomic system having n-number of degrees of freedom and without any non-potential force. 4

(d) A ring is sliding on a smooth coaxial horizontal cylinder that rotates about a vertical axis with a constant angular velocity. Find the number of holonomic constraints and degrees of freedom for this system. 2

5. (a) Check if the Frobenius power series solution is applicable for the differential equation: $x^4 y'' + y = 0$. Justify your answer. 2

(b) Expand the function $\frac{1}{|\vec{r}-\vec{r'}|}$ in a power series of $\frac{r'}{r}$, using Legendre polynomials, for $\frac{r'}{r}<1$. Hence identify the quadrupole term in the electrostatic potential $V(\vec{r})$ due a point charge Q at $\vec{r'}$.

(c) The Lagrangian $L(q_i,\dot{q}_i,t)$ undergoes a gauge transformation: 3+2

$$L' = L + \frac{dF(q_i,t)}{dt}$$

Prove that (i) the Euler-Lagrange equation of motion is invariant under this transformation but (ii) the generalized momenta change to $p_i + \frac{\partial F}{\partial q_i}$.

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2020, held in 2021

PHSACOR06T-PHYSICS (CC6)

THERMAL PHYSICS

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and any *two* questions from the rest

1. Answer any ***ten*** questions from the following: 2×10=20

(a) "Internal Energy is a state function and not a path function" — Explain.

(b) 1 kg of ice at 0°C is melted and converted to water at constant temperature. Compute its change in entropy, assuming that melting is done reversibly. The heat of fusion of water is 3.34×10^5 J/kg.

(c) Define zero on absolute scale of temperature.

(d) State the principle of equipartition of energy applicable to ideal gas molecules.

(e) Prove that $\left(\frac{\partial T}{\partial P}\right)_S = \frac{TV\alpha}{C_p}$, where the symbols have their usual meaning.

(f) State the differences between first order and second order phase transitions.

(g) Calculate the molecular diameter of nitrogen molecule if its number density $n = 2.7\times10^{25}/\text{m}^3$ and the mean free path $\lambda = 8\times10^{-8}$ m.

(h) Prove that in a *T*-*S* diagram the slope of isochoric curve is T/C_V.

(i) Using Maxwell's relations prove that $\left(\frac{\partial C_V}{\partial V}\right)_T = T\left(\frac{\partial^2 P}{\partial T^2}\right)_V$.

(j) "The Brownian motion of large particles is practically unnoticeable" — Explain.

(k) Define 'Boyle temperature' and 'critical temperature' of a real gas.

(l) State the Kelvin-Planck statement of second law of thermodynamics.

(m) Show that for a gas possessing f degrees of freedom the ratio of two specific heats $\frac{C_P}{C_V} = 1 + 2/f$.

(n) Find the Joule-Thomson coefficient for an ideal gas.

2. (a) For a group of particles (n_i is the number of particles with speed v_i):

n_i	v_i (m/s)
2	1.0
4	2.0
8	3.0
6	4.0
3	5.0

(i) Compute the average speed.

(ii) Compute the rms speed.

(iii) Find out the most probable speed.

(b) Prove that, working between the same two heat reservoirs, no engine can be more efficient than a Carnot engine. 3

(c) Show that for a hydrostatic system 2

$$\frac{dV}{V} = \beta_P\, dT - \frac{1}{B_T} dP$$

where β_P is the coefficient of volume expansion at constant pressure and B_T is the isothermal bulk modulus.

3. (a) How much work is performed by 1 mole of van der Waals gas during an isothermal expansion from volume V_1 to V_2 at temperature T? Compare it with the work done by a perfect gas. 3+1

(b) Using kinetic theory of gas, show that the coefficient of self-diffusion $D = \frac{1}{3}\lambda\vec{c}$, where λ is the mean free path and $\vec{c}$ is the average thermal velocity. 4

(c) Explain the concept of entropy in terms of disorder. 2

4. (a) Prove the following thermodynamic relations 3+3

(i) $T\,dS = C_V\, dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$

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

(b) What is inversion temperature? Show that the expression for inversion temperature for a van der Waals gas is $T_i = \frac{2a}{Rb}$. 1+3

5. (a) The Maxwell's velocity distribution for a two dimensional perfect gas is given by

$$dn = n\left(\frac{m}{2\pi KT}\right) e^{-\frac{(u^2+v^2)}{KT}}\, du\, dv$$

Here n is the number of molecules per unit area and u, v are the components of the velocity (K being the Boltzmann constant).

(i) Obtain the distribution of molecular speed between c to $c+dc$, where $c = \sqrt{u^2+v^2}$.

(ii) Find the mean square speed $\overline{c^2}$ and the most probable speed c_m.

(b) Calculate the rise in temperature of a diatomic ideal gas initially at 27°C if its pressure gets suddenly doubled. 2

(c) Show that the pressure of an ideal gas is equal to 2/3 of the translational kinetic energy of the molecules per unit volume. 2

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2020, held in 2021

PHSACOR07T-PHYSICS (CC7)

DIGITAL SYSTEMS AND APPLICATIONS

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limits as practicable.
Answers must be precise and to the point to earn credit.
All symbols are of usual significance.

Question No. 1 is compulsory and answer any *two* from the rest

1. Answer any ***ten*** questions from the following: 2×10 = 20

(a) What are the advantages and limitations of ICs?

(b) Why is delay line used in the vertical deflection system of a CRO?

(c) What is the function of aquadag in a CRT?

(d) Convert $(2598.675)_{10}$ to hexadecimal.

(e) Perform the decimal addition 679.6 + 536.8 in the 8421 BCD code.

(f) Prove the Boolean identity :

$$AB + B\bar{C} + \bar{A}(B + C) + \bar{B}C + \bar{A}\bar{B}\bar{C} + ABC = \bar{A} + B + C$$

(g) Given $\overline{AB} + \bar{A}B = C$, find $\overline{AC} + \bar{A}C$.

(h) Realise XNOR gate using only NAND gates.

(i) Draw the circuit diagram of a 4-bit subtractor.

(j) What is the need of clocking a flip-flop?

(k) What are the differences between ripple counter and parallel counter?

(l) What do you mean by edge triggering and level triggering?

(m) Find the number of flip-flops required for a MOD-5 counter.

(n) What are the main functions of a Register?

2. (a) What do you mean by deflection sensitivity of a CRT? Deduce an expression for deflection sensitivity of a CRT using magnetic deflection. Why do you use a saw-tooth voltage in a CRO? 2+3+2

(b) Design a full adder using NAND gates only. Steps of calculation in designing are required. 3

3. (a) Expand $A(\bar{A}+B)(\bar{A}+B+\bar{C})$ to maxterms and minterms.

   (b) Simplify the expression $F=(x\oplus y)\oplus(xy)$ and draw the simplified circuit.

   (c) A binary ripple counter is required to count up to $(16383)_{10}$. Find how many flip-flops are required. If the clock frequency is 8.192 MHz what is the frequency at the output of the MSB? 2+2

4. (a) On the CRO screen, the time base control is calibrated by 0.2 ms/div. One full cycle of the display covers 10 divisions on the time scale. Find the frequency of the input. 3

   (b) Convert D flip-flop to a J-K flip-flop and vice versa. 2+2

   (c) Draw a 4-bit serial-in, serial-out shift register using J-K flip-flops and show output stages. 3

5. (a) What is meant by the propagation delay in a counter? 2

   (b) Design an asynchronous mod-10 counter using J-K flip-flop. Show the output. 4

   (c) Reduce the expression $f=\sum m(0, 1, 2, 3, 5, 7, 8, 9, 10, 12, 13)$ using *K*-Map and implement the minimal expression using NAND gates. Show all intermediate steps. 4

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2019

PHSACOR05T-PHYSICS (CC5)

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and *two* other questions from the rest

1. Answer any ***ten*** questions from the following: $2\times10=20$

(a) For the function $f(x)=|x|, -1<x<1$, the Fourier series expansion for $-1<x<1$ will not contain any term of the form $\sin nx$, n being an integer. Justify statement

(b) Write Dirichlet Conditions in connection with Fourier series expansion.

(c) Show that for Laguerre equation $xy''+(1-x)y'+ny=0$ there is an essential singularity at infinity.

(d) Derive the recurrence relation for the gamma functions:

$$\Gamma(n+1)=n\Gamma(n).$$

(e) Using the generating function of Bessel function, given by

$$G(x,t)=e^{\frac{x}{2}(t-1/t)}.$$

Prove that $J_{n-1}(x)+J_{n+1}(x)=\frac{2n}{x}J_n(x)$.

(f) The error function $\mathrm{erf}(x)$ is defined by

$$\mathrm{erf}(x)=A\int_0^x e^{-z^2}dz.$$

Find the normalization of $\mathrm{erf}(x)$.

(g) Consider the differential equation,

$$x(x-1)y''+3xy'+y=0.$$

Identify its singular points and classify the singularities.

(h) What will you get if you calculate the Poisson bracket $\{p, p^2+x^2\}$, where x is the position coordinate and p is the corresponding generalized momentum.

(i) Show that the general solution of the wave equation

$$\frac{\partial^2 u}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 u}{\partial t^2},$$

is of the form $u(x,t) = f(x-ct) + g(x+ct)$.

(j) Set up the equation of motion of a one-dimensional simple harmonic oscillator using Lagrange's equation.

(k) Find the Legendre Transform of x^2.

(l) Plot schematically the functions $J_0(x)$ and $J_1(x)$ on the same graph.

(m) Three mass points are sitting on the vertices of a triangle of fixed arm-lengths. Calculate the degrees of freedom of the system.

(n) Hermite polynomials obey the following recursion relation.

$$H_{n+1}(x) = 2xH_n(x) - 2nH_{n-1}(x)$$

Given, $H_0(x) = 1$ and $H_1(x) = 2x$.

Find $H_4(x)$.

2. (a) Given, $f(x) = \begin{cases} -1, & -\pi < x < 0 \\ +1, & 0 < x < \pi \end{cases}$ 3

Expand $f(x)$ in an appropriate Fourier series of period 2π.

(b) Given, $\vec{r}_{12} = \vec{r}_2 - \vec{r}_1$, where $\vec{r}_1$ and $\vec{r}_2$ are respective position vectors of the points P_1 and P_2. Expand $\frac{1}{|\vec{r}_{12}|}$ in terms of Legendre polynomials. How do you interpret this result? 3+1

(c) Define Hamiltonian as a Legendre transform of the Lagrangian. Hence derive Hamilton's equations of motion. 1+2

3. (a) Let $f(x)$ have a Fourier series expansion, 3

$$f(x) = \sum_{n=1}^{\infty} a_n \cos nx + \sum_{n=1}^{\infty} b_n \sin nx, \ (a_n \text{ and } b_n \text{ are real constants})$$

Prove that, $\langle f^2(x) \rangle \equiv \frac{1}{2\pi}\int_{-\pi}^{\pi} f^2(x)dx = \sum_{n=1}^{\infty} \frac{a_n^2 + b_n^2}{2}$.

(b) Show that for the following equation, 2+2

$$xy'' + (1-x)y' + 4y = 0,$$

about $x = 0$, the only possible solution of the indicial equation is 0.

Find the recursion relations among the coefficients appearing in the Frobenius series.

(c) Show that for any dynamical variable u, 2+1

$$\frac{du}{dt} = \frac{\partial u}{\partial t} + \{u, H\}, \text{ where } \{\} \text{ stands for Poisson bracket.}$$

Hence prove that the Hamiltonian itself is a constant of motion when it does not explicitly depend on time.

4. (a) Write down the Lagrangian of a particle moving under the influence of a force $\vec{F} = -\frac{k}{r^2}\hat{r}$.

(b) Considering the solution of the Bessel's equation, 3

$$x^2y'' + xy' + (x^2 - n^2)y = 0,$$

in the form of $y(x) = \sum_{p=0}^{\infty} a_n x^{p+m}$, show that the roots of the indicial equation are $m = \pm n$.

(c) Define beta function $B(m, n)$ and gamma function $\Gamma(n)$. 2+2

Show that $B(m,n) = \frac{\Gamma(m)\Gamma(n)}{\Gamma(m+n)}$.

5. (a) Solve $\nabla^2\phi = 0$ using separation of variables in Cartesian coordinates. Hence find $\phi(x, y, z)$ inside a cube of side L on each face of which $\phi(x, y, z) = \phi_0$, a constant. 3+1

(b) Using Euler-Lagrange equation show that the shortest path on a plane connecting two points is a straight line. 3

(c) Starting from the Rodriguez formula: 3

$$P_l(x) = \frac{1}{2^l\, l!} \cdot \frac{d^l}{dx^l}(x^2 - 1)^l,$$

for Legendre polynomial $P_l(x)$ of degree l, show that

$$\int_{-1}^{1} P_l(x)\, P_l(x)dx = \frac{2}{2l+1}.$$

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2019

PHSACOR06T-PHYSICS (CC6)

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and any *two* questions from the rest

1. Answer any ***ten*** questions from the following: $2\times10=20$

(a) Explain what is meant by a quasi-static process. Give an example of such a process.

(b) There are 'n' number of molecules of a gas in a vessel. If the number of molecules be increased to $2n$, what will be the effect on (i) the pressure of the gas and (ii) the total energy of the gas.

(c) Why does a rubber band show a heating effect if stretched adiabatically whereas metal wires show a cooling effect in such circumstances? — Discuss with relevant mathematical expression(s).

(d) Differentiate between reversible and irreversible processes. Give necessary condition for the reversibility of a process.

(e) Calculate the collision frequency and molecular diameter of air molecules at N.T.P. given that the viscosity $\eta=1.7\times10^{-5}$ Ns/m^2, mean velocity $\bar{c}=4.5\times10^2$ m/s and $\rho=1.29$ kg/m^3.

(f) "The entropy of the universe is increasing." — Explain.

(g) Show that $G=-S^2\left\{\frac{\partial}{\partial S}(H/S)\right\}_P$ where the symbols have their usual meanings.

(h) Show that no engine can be more efficient than a reversible engine operating between the same two reservoirs.

(i) State the basic differences between first order and second order phase transitions.

(j) The velocities of twenty molecules are 1, 1, 2, 3, 3, 3, 4, 5, 5, 5, 5, 5, 5, 6, 6, 7, 7, 8, 8 and 9 unit. Find the average, R.M.S and most probable velocity of the molecules.

(k) Express the van der Waal's equation of state in virial form,
$PV=RT\left[1+\frac{B}{V}+\frac{C}{V^2}+.....\right]$ to find the coefficients B and C.

(l) Can a room be cooled by leaving the door of an electric refrigerator open? — Explain.

(m) Plot Maxwell speed distribution curve for the temperature T_1, T_2 and T_3 where $T_3>T_2>T_1$.

(n) Calculate the change in the melting point of ice at 0°C when the pressure is increased by 2 atms. Latent heat of fusion of ice is 80 cal/gm and specific volume of water and ice are 1.0001 and 1.0908 c.c. respectively.

Answer any *two* questions from the following $10\times2=20$

2. (a) Draw a Carnot cycle diagram on a T-S plane and hence show that for a Carnot cycle, $\frac{T_1}{T_2}=\frac{Q_1}{Q_2}$ where T_1 and T_2 are temperatures of the source and sink respectively and Q_1 is the amount of heat absorbed from the source and Q_2 is the amount of heat rejected to the sink. 2+2

(b) Calculate the increase of entropy of 1 kg of ice when it is converted into steam. Given specific heat of water 1 kcal/kg °C, latent heat of ice 80 kcal/kg and latent heat of steam 540 kcal/kg. 3

(c) Show that $\gamma=1+\frac{2}{f}$, where $\gamma=\frac{C_P}{C_V}$ and f is the degree of freedom. 3

3. (a) Maxwell's energy distribution law is given by the relation $n(\varepsilon)d\varepsilon = A\sqrt{\varepsilon}\ e^{-\varepsilon/kT}$, where $n(\varepsilon)d\varepsilon$ is the number of gas molecules having energy between ε and $\varepsilon+d\varepsilon$. Calculate the normalization constant A, where the total number of molecules is N. Also find the average and the most probable energy of the system. 'k' stands for Boltzmann constant. 3+2+2

(b) Starting from the expression of Helmholtz free energy $F(T,V)$, show that the heat capacity at constant volume is $C_V=-T\left(\frac{\partial^2 F}{\partial T^2}\right)_V$. 3

4. (a) Obtain Clausius-Clapeyron's equation for 1st order phase transition. 3

(b) The equation of state of real gas is $P(V-b)=RT\ \exp(-a/RTV)$ where 'a' and 'b' are constants. Find the inversion temperature of the gas. 3

(c) Derive Einstein's equation for mean square displacement of Brownian particle. 4

5. (a) Explain the principle of cooling of a paramagnetic substance by adiabatic demagnetisation. Give a schematic diagram of the experimental arrangement of adiabatic demagnetisation for the production of low temperature. Find a thermodynamic expression for the amount of cooling. $1+1\frac{1}{2}+2\frac{1}{2}$

(b) (i) Justify that Joule-Thomson's Porous plug experiment can also be called adiabatic throttling process. 2

(ii) Show that the Joule-Thomson coefficient is given by 2

$$\mu=-\frac{1}{C_P}\left(\frac{\partial U}{\partial P}\right)_T-\frac{1}{}\left\{\frac{\partial(PV)}{\partial P}\right\}_T.$$

(iii) Why do He and H_2 show heating effect instead of cooling during the Joule-Thomson porous plug experiment? 1

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WEST BENGAL STATE UNIVERSITY

B.Sc. Honours 3rd Semester Examination, 2019

PHSACOR07T-PHYSICS (CC7)

DIGITAL SYSTEMS AND APPLICATIONS

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.
Candidates should answer in their own words and adhere to the word limit as practicable.
All symbols are of usual significance.

Answer Question No. 1 and any *two* from the rest

1. Answer any ***ten*** questions: 2×10 = 20

(a) What are active and passive electronic components? Give examples.

(b) Why a time base signal is used in a CRO?

(c) Subtract $(1011)_2$ from $(11011)_2$ by 2'S complement method.

(d) Convert $(DB19)_{16}$ to octal number.

(e) What do you mean by minterms and maxterms?

(f) Draw functional block diagram of a 555 timer IC.

(g) Prove using boolean logic the identity

$$A + AB + AB = 1$$

(h) Design a 1:2 Demultiplexer.

(i) Draw the block diagram of 3-bit synchronous counter.

(j) What is the function of an encoder?

(k) What is the difference between RAM and ROM?

(l) What is the difference between latch and flip flop?

(m) Classify registers in respect of operation.

(n) Draw a circuit of parity checker using logic gates.

2. (a) Give the block diagram of a general purpose CRO. How can the phase difference between two AC voltages be measured using CRO? 2+2

(b) An unknown sinusoidal voltage is displayed on the CRO screen. If the peak to peak distance of the displayed waveform is 8 divisions of the vertical scale and V/div control is set at 5 mV/div. Find the r.m.s value of a.c. voltage. 3

(c) Draw a circuit of 4:1 multiplexer, give its logic equation and truth table. 3

3. (a) Given the truth table.

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

(i) Find the logic equation.

(ii) Simplify it using Karnaugh map.

(iii) Draw the simplified logic circuit.

(b) Show that a NAND-NAND configuration is equivalent to a AND-OR configuration. 2

(c) Draw an ADDER circuit using logic gates. 2

(d) Draw the circuit of a NAND gate using discrete components. 2

4. (a) Draw the circuit diagram of a J-K flip flop. Give its truth table and explain race-around condition. 1+1+2

(b) Draw the circuit diagram of a D-type and T-type flip flop using J-K flip flop. 1+1

(c) Draw the circuit diagram of an astable multivibrator using 555 timer. 2

(d) What is edge triggering? Explain. 2

5. (a) Construct a 4-bit shift register using J-K flip flop. Write down a table of the readings of the shift register after each clock pulse by assuming the data '1011'. 2+2

(b) Explain with the help of relevant circuit diagram the operation of decade counter. 2+2

(c) Show the timing diagram of a 3-bit synchronous counter. 2

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