2026

PHYSICS

(Major)

Paper : PHY0600104

(Nuclear and Particle Physics)

Full Marks : 60

Time : 2½ hours

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

1. Answer the following questions : 1×8=8

(a) What is the relation between mass number and nuclear radius?

(b) Why are even-even nuclei most stable?

(c) What is the relation between mean-life time and half-life time of a radioactive substance?

(d) Why is energy of α-particles discrete in α-decay?

(e) What is the difference between X-rays and γ-rays?

(f) At what scattering angle is the wavelength shift in Compton effect equal to the Compton wavelength?

(g) Write the principle of gas-filled detector.

(h) What is the difference between π-mesons and K-mesons?

2. Answer any *six* of the following questions : 2×6=12

(a) What is the mass number A of a nucleus whose radius R is 2·5 fm?

(b) Justify that the nuclei are made of protons and neutrons rather than protons and electrons.

(c) If the half-life of a radioactive substance is 30 days, then calculate its decay constant.

(d) A radioactive nucleus disintegrates according to the following sequence :

$$X \xrightarrow{\beta} X_1 \xrightarrow{\alpha} X_2 \xrightarrow{\alpha} X_3$$

If the mass number and atomic number of X_3 are 172 and 69 respectively, what is the mass number and atomic number of X?

(e) Write any two features of Cherenkov radiation.

(f) A proton is stopped in an ionization chamber producing 10^5 ion-pairs. Energy required to produce an ion-pair is 35 eV.

(i) What is the kinetic energy of proton entering the ionization chamber?

(ii) What is the amount of charge collected on each plate?

(g) Explain why, in nuclear fission, the neutrons are more effective as the bombarding particle.

(h) In a star, three α-particles fuse together to form a $^{12}_{6}C$ nucleus. Calculate the energy released in the reaction. Given—

$M(^{4}_{2}He) = 4{\cdot}002604$ amu

$M(^{12}_{6}C) = 12$ amu

(i) Explain the concept of charge conjugation.

(j) Give the quark structure of a proton and neutron.

3. Answer any *four* of the following questions : 5×4=20

(a) Explain the terms 'packing fraction', 'mass defect' and 'binding energy' of a nucleus. How is binding energy related with the stability of the nucleus? 3+2=5

(b) Calculate the average binding energy per nucleon for a U^{238} nucleus in MeV. The mass of U^{238} atom is 238·05078 amu and it is composed of 92 protons and 146 neutrons. The masses of proton, neutron and electron are 1·00728 amu, 1·00867 amu and 0·00055 amu respectively. 5

(c) Explain qualitatively the phenomenon of γ-decay in nuclei. 5

(d) Write a short note on any *one* of the following : 5

(i) Ionization chamber

(ii) Proportional counter

(e) Derive an expression for the change in wavelength of scattered photon in Compton scattering. 5

(f) Distinguish between nuclear fission and fusion. Explain the principle of a nuclear reactor. 2+3=5

(g) Discuss the classification of elementary particles. 5

(h) Obtain the classical formula for energy loss of heavy charged particles through matter and then introduce relativistic correction to obtain Bethe-Bloch formula. 5

4. Answer any *two* of the following questions : 10×2=20

(a) State the laws of radioactive disintegration and derive the Rutherford-Soddy law. Explain the term 'mean-life' of a radioactive substance. Show that the mean-life of an atom of a radioactive substance is the reciprocal of its decay constant. 5+5=10

(b) Plot the distribution of kinetic energy of β-particles and state why the energy distribution of β-decay is continuous. How did it lead to discovery of neutrino? Explain Pauli's neutrino hypothesis for β-decay from a radioactive nucleus. 1+2+2+5=10

(c) Describe the construction and working of a Geiger-Muller (GM) counter. What are its limitations? 8+2=10

(d) What is *Q*-value of nuclear reaction? How can it be determined? Calculate the *Q*-value of the following reaction :

$$^{3}_{1}\mathrm{H} + ^{2}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + ^{1}_{0}n$$

(Continued)

Given—

$M(^{3}_{1}\mathrm{H}) = 3{\cdot}0169982$, $M(^{2}_{1}\mathrm{H}) = 2{\cdot}0147361$,

$M(^{4}_{2}\mathrm{He}) = 4{\cdot}0038727$, $M(^{1}_{0}n) = 1{\cdot}0089832$

all in amu. Also mention the above reaction is exoergic or endoergic. 2+3+4+1=10

(e) What are baryons and leptons? Explain the conservation law for lepton and baryon number with example. 4+6=10

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2026

PHYSICS

(Major)

Paper : PHY0600204

(Digital Electronics)

Full Marks : 45

Time : 2 hours

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

1. Answer the following as directed : 1×5=5

(a) In an IC, silicon dioxide (SiO_2) acts as

(i) a substrate layer

(ii) an insulating layer

(iii) a transistor

(iv) a resistor

(Choose the correct option)

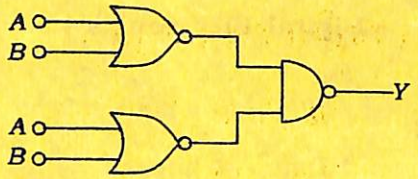
(b) BCD code is also called _____ code.

(Fill in the blank)

(c) Sequential circuits are slower than the combinational circuits.

(State True or False)

(d) For the given circuit diagram



the output Y is

(i) $A+B$

(ii) AB

(iii) $\overline{A+B}$

(iv) $\overline{A \cdot B}$

(Choose the correct option)

(e) The storage capacity of each stage in a shift register is _____ bits.

(Fill in the blank)

2. Answer any *five* of the following questions : 2×5=10

(a) Convert the following hexadecimal numbers to binary :

(i) D45

(ii) AC3·6

(b) Obtain the SOP form of the function

$$Y = AB + ACD$$

(c) Simplify the following expression with the help of Boolean algebra rules :

$$Y = ABC[AB + \overline{C}(BC + AC)]$$

(d) Using 2's complement, perform the subtraction

$$(19)_{10} - (25)_{10}$$

(e) Draw the external circuit diagram of an IC 555 used as an astable multivibrator.

(f) Draw the logic diagram of a clocked *S-R* flip-flop. Write the characteristic equations of *S-R* flip-flop.

(g) What are shift registers? What are the basic types of shift registers?

(h) Mention two differences between active and passive components of IC.

(i) What are low- and high-level languages? Give examples.

(j) Draw the logic symbol of XOR gate and construct the truth table.

3. Answer any *four* of the following questions : 5×4=20

(a) Using NAND gates only, realize the following gates :

(i) AND

(ii) OR

(iii) NOT

(b) Draw the logic circuit for the following function using NOR gates :

$$(A+B)(B+C)(A+C)$$

(c) Simplify the Boolean function

$F(A, B, C, D) = \Sigma m(7, 9, 10, 11, 12, 13, 14, 15)$ with the help of K-maps.

(d) Express the function $Y = A + \overline{B}C$ in (i) canonical SOP and (ii) canonical POS forms.

(e) Explain the function of a D flip-flop using a suitable diagram. Write the characteristic table of a D flip-flop.

(f) What is half adder? Draw the logic diagram and write the truth table of a half adder.

(g) Distinguish between static RAM and dynamic RAM. What is a cache memory? What is its function?

(h) Distinguish between combinational and sequential logic circuits. What do you mean by latch? Draw the circuit diagram of a bistable multivibrator of a flip-flop.

4. Answer any *one* of the following questions : 10

(a) Draw the block diagram and truth table of a full subtractor. Design a full subtractor logic circuit by using K-map. 5+5=10

(b) (i) Draw the logic diagram of a master-slave *J-K* flip-flop and explain its operation with the help of a truth table. 6

(ii) What is race-around condition of a *J-K* flip-flop? How is the race-around condition eliminated? 4

(c) Draw the pinout diagram of IC 555. Explain the working of an astable multivibrator with duty cycle more than 50% using IC 555 timer and draw the relevant waveforms. 2+8=10

(d) Write short notes on any *two* of the following : 5×2=10

(i) Full Adder

(ii) CPU and ALU

(iii) Serial-In Serial-Out Shift Register

(iv) MAR and MDR

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PHYSICS

(Major)

Paper : PHY0600304

(Astronomy and Astrophysics)

Full Marks : 60

Time : 2½ hours

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

1. Answer the following : 1×8=8

(a) What do you mean by Stellar parallex?

(b) Write the Chandrasekhar limit for white dwarf mass.

(c) Convert 1 parsec into light year.

(d) How does the life time of a star on the main sequence vary with mass?

(e) What is Aladin?

(f) Place the following spectral types in order of decreasing temperatures :

A, B, F, K, G, M, O

(g) What are Lenticular Galaxies?

(h) List the terrestrial planets.

2. Answer any *six* of the following : 2×6=12

(a) The distance of a star is 100 pc and its apparent magnitude is 6. Find its absolute magnitude.

(b) Draw a schematic ray diagram of a Newtonian reflecting telescope.

(c) Calculate the resolving power of a telescope having a diameter 2·34 m, when a radiation of wavelength 5500 Å is detected.

(d) Write the differences between asteroids and meteoroids.

(e) What is Kuiper belt? What is its shape?

(f) Write two major differences between elliptical galaxies and spiral galaxies.

(g) What are cosmic voids and how do they form?

(h) State the cosmological principle and its significance in cosmology.

(i) What is H-R diagram? Sketch H-R diagram showing all groups of stars.

(j) What is neutron star? What is its mass?

3. Answer any *four* of the following : 5×4=20

(a) Define apparent and absolute magnitudes of a star. Deduce the relation between them. 1+1+3=5

(b) What is light gathering power of a telescope? Compare the light gathering power of the 8 m telescope and 0·8 m telescope. 2+3=5

(c) Using Stefan-Boltzmann law of radiation, obtain the ratio of radii of two stars in terms of their surface temperatures and absolute magnitudes.

(d) Explain the significance of Stellar mass in respect of evolution of stars. Estimate the life time of stars on the main sequence. 2+3=5

(e) Explain how the objects in the solar system are classified.

(f) What is Milky way? Mention its different components. Draw a schematic diagram of the Milky way showing all the components. 1+2+2=5

(g) State Hubble's law and explain how Hubble's constant indicates the age of the universe. 2+3=5

(h) What are Cepheid Variable Stars? Explain how the Cepheid Variable Stars can be used to find distances of nearby stars. 1+4=5

4. Answer any *two* of the following : 10×2=20

(a) *(i)* Explain how the distance of a nearby star can be determined using trigonometric parallex method. 5

(ii) Distinguish between reflecting and refracting telescope. What are the advantages of reflecting telescope over the refracting telescope? 3+2=5

(b) (i) What do you understand by hydrostatic equilibrium in a star? Derive the equation of hydrostatic equilibrium for a star. 2+4=6

(ii) Calculate the ratio of fluxes received from two stars whose apparent magnitudes differ by 2·5. 4

(c) (i) What are the three principal layers of Sun's atmosphere? Explain the layers briefly. 2+6=8

(ii) What is Asteroid Belt? Where is it located? 1+1=2

(d) (i) Draw the Hubble's tuning fork diagram and describe the classification scheme of the galaxies. 3+4=7

(ii) Describe the Kant-Laplace nebular hypothesis for the formation of solar system. 3

(e) Write short notes on any *two* of the following : 5×2=10

(i) Oort cloud

(ii) Cosmic Microwave Background Radiation (CMBR)

(iii) PP and CNO cycle

(iv) Star clusters

(v) Virial theorem

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2026

PHYSICS

(Major)

Paper : PHY0600404

(Statistical Mechanics)

Full Marks : 60

Time : 2½ hours

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

1. Answer the following questions as directed : 1×8=8

(a) Define phase space.

(b) If one system is composed of N identical and indistinguishable fermions, then write down the expression of total number of microstates corresponding to a macrostate specified by the set of occupation numbers $\{n_1, n_2, \cdots\}$.

(c) Give one example of fermions.

(d) According to which statistics, the energy at absolute zero cannot be zero?

(i) Maxwell-Boltzmann statistics

(ii) Bose-Einstein statistics

(iii) Fermi-Dirac statistics

(iv) None of the above

(Choose the correct option)

(e) What is ultraviolet catastrophe?

(f) Bose-Einstein condensates have

(i) very low kinetic energy

(ii) low kinetic energy

(iii) high kinetic energy

(iv) highest kinetic energy

(Choose the correct option)

(g) Name the statistics where Pauli exclusion principle is used.

(h) Under what condition quantum statistics approaches the classical statistics?

2. Answer any *six* questions from the following : 2×6=12

(a) Explain the meaning of ensemble in statistical mechanics.

(b) Calculate the radiant energy by a black-body at a temperature of 4000 K in MKS system.

(c) Write one similarity and one difference between Bose-Einstein and Fermi-Dirac statistics.

(d) What is degenerate Bose gas?

(e) Fermions are distributed in three energy states having energies $-E$, 0 and $+E$ respectively. Determine the value of energy of the macrostate (7, 8, 5).

(f) Explain the significance of partition function in statistical thermodynamics.

(g) Mention the characteristics of the particle upon which Bose-Einstein statistics is applicable.

(h) Calculate the temperature of a star when it radiates maximum energy at a wavelength 550 nm. Given Wien's constant $b = 2 \cdot 90 \times 10^{-3}$ mK.

(i) What is the minimum size of a phase space cell in classical and quantum mechanical system?

(j) Give one example of Bose gas and state its behaviour at temperature near zero Kelvin (~ 2·17 *K*).

3. Answer any *four* of the following : 5×4=20

(a) Discuss the term 'microstate'. Consider that two particles are to be distributed in an energy level which is 3-fold degenerate. Find the possible microstates if the particles are—

(i) distinguishable;

(ii) indistinguishable bosons;

(iii) indistinguishable fermions. 2+3=5

(b) Derive the Sackur-Tetrode equation for the entropy of an ideal monoatomic gas. How does it resolve the Gibbs paradox? 4+1=5

(c) What is radiation pressure? Derive an expression of diffused radiation pressure. 1+4=5

(d) Write statistical definition of entropy. Derive the relation between entropy and thermodynamic probability. 1+4=5

(e) What is degenerate Fermi gas? Give one example of a highly degenerate Fermi system. What is the Fermi energy for copper, given density = 9 g cm^{-3}, atomic weight = 63·5 and valency equal to one? 1+1+3=5

(f) Using Maxwell-Boltzmann statistics, prove the law of equipartition of energy. 5

(g) What is blackbody radiation? Discuss the experimental curve of blackbody radiation. 5

(h) What do you mean by occupation index for each state in F-D statistics? An ideal Fermi gas is confined inside a container that is connected to particle reservoir. Each particle can occupy discrete set of single particle quantum states. If the probability that a particle quantum state is unoccupied is 0·1, then what is the average number of fermions in that state? 2+3=5

4. Answer any *two* questions of the following : 10×2=20

(a) Derive Maxwell-Boltzmann law of energy distribution.

(b) What is Fermi energy? Derive the expression of Fermi energy. Discuss the effect of temperature on Fermi distribution function. 1+4+5=10

(c) Using Bose-Einstein statistics, derive an expression of pressure of a perfect gas. Is Maxwell-Boltzmann distribution a limiting case of Bose-Einstein's distribution? If yes, explain. 8+2=10

(Continued)

(d) Write short notes on : 5+5=10

(i) White dwarf stars

(ii) Rayleigh-Jeans law

(e) Write the difference between photon and ideal gas. Starting from B-E statistics distribution law, derive Planck's law. 2+8=10

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