

P-3/PHSG/04 (A)/2017 (N)

2017

PHYSICS

(General)

FOURTH PAPER

(Group—A)

(Part—III / 2008 Syllabus)

Full Marks : 70

Time : 3 hours

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

Answer **all** questions

1. Answer the following questions : $1 \times 10 = 10$

- (a) What do you mean by 'proper length'?
- (b) What is Galilean invariance?
- (c) Using NOR gate, draw the diagram for OR gate.
- (d) What is meant by electron-positron pair production?
- (e) Up to which frequency range, coaxial cables are used for propagation of electromagnetic waves?

(2)

- (f) What do you mean by free particle?
- (g) What is the difference between 'bit' and 'byte'?
- (h) Give two examples where classical mechanics fails and quantum mechanics successfully explains them.
- (i) Draw the logic circuit of half adder.
- (j) What do you mean by thermal neutrons?
2. (a) (i) What was the aim of Michelson-Morley experiment? Did he get positive result?
- (ii) Calculate the velocity at which electron mass is $\sqrt{3}$ times the rest mass.
- (iii) Show that $x^2 + y^2 + z^2 - c^2 t^2$ remains invariant under Lorentz transformation.
- (iv) What is pseudoforce? 2+2+4+2=10

Or

- (b) (i) Establish Einstein's mass-energy relationship.
- (ii) State the basic postulates of Einstein's special theory of relativity.

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(Continued)

(3)

- (iii) Prove that a particle of rest mass m_0 , moving with a velocity V has a changed mass given by

$$m = \frac{m_0}{\sqrt{1 - \frac{V^2}{c^2}}} \quad 4+2+4=10$$

3. (a) (i) Discuss the theory of successive disintegration of radioactive substance and obtain the condition for secular equilibrium from it.
- (ii) State the laws of radioactive decay and deduce the relation $N = N_0 e^{-\lambda t}$, where the symbols have their usual meanings.
- (iii) What is the relation between nuclear radius and its mass number? 5+4+1=10

Or

- (b) (i) Explain the energy spectrum curve obtained from β -decay of a radioactive nucleus.
- (ii) What are the primary cosmic rays and secondary cosmic rays?
- (iii) The activity of certain radionuclide decreases to 15% of its original value in 10 days. Find its half-life.
- (iv) What is Compton scattering? 3+2+3+2=10

3+2+3+2=10

(Turn Over)

M7/424

(4)

- ✓ 4. (a) (i) What is metastable state? What is its importance in laser production?
- (ii) Explain how Maxwell generalized Ampere's circuital law.
- (iii) What do you mean by graded-index fibre? Discuss its advantage over step-index fibre. (2+2)+2+(2+2)=10

Or

- (b) (i) Show that the direction of propagation of electromagnetic wave, electric field vector \vec{E} and the magnetic field vector \vec{H} are perpendicular to each other.
- (ii) Explain the terms 'population inversion' and 'optical pumping'. 6+(2+2)=10

- ✓ 5. (a) (i) How can you design AND gate, using NAND gate only?
- (ii) Construct a digital half-adder circuit, using logic gates and explain its action.
- (iii) Show using Boolean algebra that $\overline{AB} + \overline{A} + AB = 1$ and $A + \overline{AB} = A + B$
2+(2+2)+(2+2)=10

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(Continued)

(5)

Or

- (b) (i) State De Morgan's theorem. Verify De Morgan's theorem by using 3-input gate truth table.

(ii) What is flowchart?

- (iii) Write a BASIC program to find the solution of the quadratic equation

$$ax^2 + bx + c = 0$$

where a , b and c are given as input.

$$(2+3)+1+4=10$$

- ✓ 6. (a) (i) Write Planck's energy distribution law of blackbody radiation. Hence derive Wien's displacement law.
- (ii) Describe briefly Davisson-Germer experiment in support of wave character of particles. (2+3)+5=10

Or

- (b) (i) A proton and an electron have the same kinetic energy. Which has longer wavelength?
- (ii) State Rayleigh-Jeans law about blackbody radiation and discuss the limitations of this laws.
- (iii) From Heisenberg's uncertainty principle, prove that electrons cannot exist inside the nucleus.

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(Turn Over)

(6)

- (iv) Why is de Broglie hypothesis not applicable in macroscopic world?
2+(2+1)+3+2=10

- ✓ 7. (a) (i) If $i\hbar \frac{\partial}{\partial x}$ is an eigenoperator to the function e^{-ikx} , then find the corresponding eigenvalue.
- (ii) What do you mean by Hermitian operator? Show that such type of operators always possess real eigenvalue.
- (iii) What is the significance of probability density?
- (iv) What is zero-point energy?
2+(2+2)+2+2=10

Or

- (b) (i) Solve the Schrödinger's wave equation for a particle confined in a one-dimensional box.
- (ii) Draw the energy-level diagram for a particle confined in a one-dimensional potential well.
- (iii) Represent position, momentum and energy by quantum mechanical operator.
5+2+3=10

M7/424

(Continued)

P-3/PHSG/04 (A)/2016 (N)

2016

PHYSICS

(General)

FOURTH PAPER

(Group—A)

(Part—III / 2008 Syllabus)

Full Marks : 70

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer all questions

1. Answer the following questions : 1×10=10

- ✓ (a) Why is the light called an electromagnetic wave?
- (b) What was the aim of Michelson-Morley experiment?
- ✓ (c) State Geiger-Nuttall rule.
- (d) On what factors the range of α -particles depends?

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(Turn Over)

(2)

- (e) What is a metastable state?
(f) What is the time dispersion?
(g) What is the function of RAM?
(h) Write down the utility of flowchart.
(i) Write truth table of XOR gate.
(j) Write down the connectivity between observable and Hermitian operators.
2. (a) (i) What do you mean by inertial and non-inertial frames for reference?
(ii) Discuss 'length contraction' and 'time dilation'.
(iii) Two particles are moving along a straight line towards each other with uniform velocity of $0.6c$ and $0.5c$ respectively. Calculate the relative velocity of approach between them.
 $2 + (2\frac{1}{2} + 2\frac{1}{2}) + 3 = 10$

Or

- (b) (i) What is Galilean invariance?
(ii) Under which condition the Lorentz transformation equations will reduce to Galilean transformation?
(iii) What do you mean by proper length?

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(Continued)

(3)

- (iv) How much energy will be evolved when 1 gm mass is completely transformed into energy?

(v) State the basic postulates of Einstein's special theory of relativity.
 $2 + 2 + 2 + 2 + 2 = 10$

3. (a) (i) Define packing fraction. ✓
(ii) Define Q value of a nuclear reaction. Derive an expression for the Q value of the reaction $X(a, b)Y$.
(iii) Give simple explanation of nuclear fission by liquid-drop model.
 $2 + (2 + 3) + 3 = 10$

Or

- (b) (i) What is the relation between nuclear radius and its mass number?
(ii) Give a brief account of pair production and electron-positron annihilation. ✓
(iii) What is neutrino hypothesis and how are the discrepancies of β emission removed using this hypothesis?
 $2 + (2 + 2) + (2 + 2) = 10$

(Turn Over)

M16/1058

(4)

4. (a) (i) Write Maxwell's equations of electromagnetic field. ✓
(ii) Derive an expression for Poynting vector and explain its significance. ✓
(iii) Discuss the elementary idea of holography. Also mention two uses of holography. ✓
 $2+4+(3+1)=10$

Or

- (b) (i) What is population inversion? ✓
(ii) Explain the terms 'spontaneous emission' and 'stimulated emission'. Hence derive the expression for Einstein's A and B coefficients. ✓
(iii) What is optical fibre? Explain its working principle. ✓
 $1+(1+1+4)+3=10$
5. (a) (i) Draw the circuit diagram of a NOT gate using transistor and discuss its working. ✓
(ii) Discuss with truth table, the working principle of an R - S flip-flop. ✓
(iii) Show using Boolean algebra that
 $A + \bar{A}B = A + B$ $(2+3)+3+2=10$

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(Continued)

(5)

Or

- (b) (i) Write a BASIC program to determine whether a given number is prime or not. ✓
(ii) What are the functions of essential parts of a computer? ✓
(iii) What is meant by 2's complement of a binary number? ✓
(iv) Using logic gate draw the circuit of a half-adder. ✓
 $3+3+2+2=10$
6. (a) (i) Mention the nature of radiant heat. ✓
(ii) Derive Planck's energy distribution law of blackbody radiation. ✓
(iii) Calculate the de Broglie wavelength of an electron whose kinetic energy is 2000 eV. (Given, mass of electron $= 9.1 \times 10^{-31}$ kg.) ✓
 $2+5+3=10$

Or

- (b) (i) State and explain Heisenberg's time-energy uncertainty principle. ✓
(ii) From Heisenberg's uncertainty principle, prove that electrons cannot exist inside the nucleus. ✓

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(Turn Over)

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PHYSICS
(General)

FOURTH PAPER

(Group—A)

(Part—III / 2008 Syllabus)

Full Marks : 70

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer all questions

- (iii) Why is the wave nature of moving body considered only in case of small particles?
- (iv) Write Bohr's complementary principle. 3+3+2+2=10
7. (a) (i) Write the physical significance of a wave function.
- (ii) Show that momentum operator is Hermitian in nature.
- (iii) What is zero point energy?
- (iv) Draw the energy-level diagram for a particle confined in a one-dimensional potential well. 3+3+2+2=10

Or

- (b) (i) Derive the time-dependent Schrödinger equation from the idea of quantum mechanical operators and hence solve it by the method of separation of variables.
- (ii) The wave function of a particle is given by
- $$\psi_n(x) = A \sin \frac{n\pi x}{a}, \text{ when } 0 < x < a$$
- $$= 0, \text{ when } x < 0 \text{ and } x > a$$
- Find the normalized form of the wave function. (3½+3½)+3=10

1. Answer the following questions : 1×10=10

- (a) What is Galilean invariance?
- (b) Under which condition the Lorentz transformation equations will reduce to Galilean transformation?
- (c) Write two characteristics of nuclear forces.
- (d) What is electron-positron pair production?
- (e) What is Poynting vector?

(2)

- (f) What is population inversion?
- (g) Find the sum of the binary numbers $(10110)_2$ and $(11011)_2$.
- (h) Why is NAND gate called a universal gate?
- (i) State Heisenberg's uncertainty principle in terms of energy and time.
- (j) What is zero-point energy?
2. (a) (i) Derive space-time Lorentz transformation relations.
- (ii) What is fictitious force? Give an example.
- (iii) Calculate the velocity at which electron mass is $\sqrt{2}$ times the rest mass. $5+(2+1)+2=10$

Or

- (b) (i) Explain the significance of the result of Michelson-Morley experiment.
- (ii) Prove that a particle of rest mass m_0 , moving with a velocity v has a changed mass given by

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

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(Continued)

(3)

- (iii) Find the ratio of the mass of an electron of 1000 MeV kinetic energy and its rest mass. Given, rest mass of electron = 0.51 MeV. $3+4+3=10$
3. (a) (i) Define half-life of a radioactive nuclei. Derive a relation between half-life and radioactive decay constant.
- (ii) Discuss the theory of successive disintegration of radioactive substance and obtain the condition for secular equilibrium from it.
- (iii) What is Compton scattering? $(1+3)+5+1=10$

Or

- (b) (i) Give simple explanation of nuclear fission by liquid-drop model.
- (ii) State Geiger-Nuttall rule.
- (iii) Mention any four properties that remain conserved in a nuclear reaction.
- (iv) Write the characteristics of neutrino.
- (v) What are the primary cosmic rays and secondary cosmic rays? $3+1+2+2+2=10$

M15-770/887

(Turn Over)

(4)

4. (a) (i) Write Maxwell's equations of electromagnetic field.
(ii) Derive the expression for energy density in an electromagnetic wave.
(iii) Explain how Maxwell generalized Ampere's circuital law. $2+5+3=10$

Or

- (b) (i) What do you mean by graded-index fibre? Discuss its advantage over step-index fibre.
(ii) What are the advantages of optical fibre over the communicating media?
(iii) What is a metastable state? Write down its significance in the case of LASER. $(2+2)+2+(1+3)=10$

5. (a) (i) What is the difference between RAM and ROM?
(ii) What is flowchart? Draw a flowchart to find the sum of square of first N -natural numbers.
(iii) Show that $A + AB + \bar{A}B = \bar{A}\bar{B}$.
(iv) What is meant by 2's complement of a binary number? $2+(1+3)+3+1=10$

(5)

Or

- (b) (i) Discuss with truth table the working principle of an R-S flip-flop. 4
(ii) What is XOR gate? Write its truth table. NAND (NAND)
(iii) Sketch a basic NOR gate and write its truth table. $5+(1+2)+2=10$

6. (a) (i) Establish Kirchhoff's law of radiation.
(ii) State and explain de Broglie hypothesis of matter wave.
(iii) Describe Davisson-Germer experiment in support of wave character of particles. $3+2+5=10$

Or

- (b) (i) State Rayleigh-Jeans law about blackbody radiations and discuss its limitations. Wien's law
(ii) Discuss Planck's quantum hypothesis. Derive Stefan's law from Planck's radiation law.
(iii) Calculate the de Broglie wavelength of an electron whose kinetic energy is 1000 eV. Given, mass of electron $= 9.1 \times 10^{-31}$ kg. $(2+1)+(2+3)+2=10$

(6)

P-3/PHSG/04 (A)/2014 (N)

2014

PHYSICS

(General)

FOURTH PAPER

(Group—A)

(Part—III / 2008 Syllabus)

Full Marks : 70

Time : 3 hours

The figures in the margin indicate full marks
for the questions

Answer all questions

7. (a) (i) What is the need for normalization of wave function?

(ii) The wave function of a particle is given by

$$\Psi_n(x) = A \sin \frac{n\pi x}{a}, \text{ when } 0 < x < a$$
$$= 0, \text{ when } x < 0 \text{ and } x > a$$

Find the normalized form of the wave function.

(iii) Represent position, momentum and energy by quantum mechanical operator.

(iv) What is significance of probability density? 2+3+3+2=10

Or

(b) (i) What do you mean by Hermitian operator? Show that such type of operators always possess real eigenvalues.

(ii) Consider a particle in a box of length L . The potential inside the box is zero. Show that

$$\psi(x, t) = C_n \exp\left(\frac{-iE_n t}{\hbar}\right) \sin \frac{n\pi x}{L}$$

$$\text{where } E_n = \frac{n^2 \pi^2 \hbar^2}{2mL^2} \quad (2+3)+5=10$$

M15-770/887

(Continued)

1. Answer the following questions : 1×10=10

(a) What do you mean by 'pseudoforce'?

(b) Define packing fraction.

(c) Write the significance of Rutherford α -ray scattering experiment.

(d) What is population inversion?

(e) Write the truth table of XOR gate.

(f) State Wien's radiation law.

14M-790/869

(Turn Over)

(2)

- (g) Write the quantum-mechanical operators of momentum and energy.
- (h) What do you mean by universal gate?
- (i) What is the use of the BASIC statement 'KILL'?
- (j) What do you mean by normalization of wave function?
2. (a) (i) Discuss the concept of space, time and mass according to Newtonian mechanics.
- (ii) Discuss 'length contraction' and 'time dilation'.
- (iii) What is Galilean invariance?
 $3+(2\frac{1}{2}+2\frac{1}{2})+2=10$

Or

- (b) (i) What are the differences between Newtonian relativity and Einstein's relativity?
- (ii) According to special theory of relativity, discuss the simultaneity of two events.
- (iii) Show that $x^2 + y^2 + z^2 - c^2t^2$ remains invariant under Lorentz transformation.
 $2+4+4=10$

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(Continued)

(3)

3. (a) (i) Explain the energy spectrum curve obtained from β -decay of a radioactive nuclide.
- (ii) Show that the law of conservation of energy and momentum are not obeyed in β -decay. Show how neutrino hypothesis removes this discrepancy.
 $3+(4+3)=10$

Or

- (b) (i) Define Q-value of a nuclear reaction. Derive an expression for the Q-value of the reaction $X(\alpha, b)Y$.
- (ii) Show by mass-energy calculations whether the reaction $N^{14}(\alpha, p)O^{17}$ is exoergic or endoergic. Given, atomic masses of ${}^7N^{14}$, ${}^2He^4$, ${}^8O^{17}$ and ${}^1H^1$ are 14.00753 a.m.u., 4.00260 a.m.u., 17.00450 a.m.u. and 1.00814 a.m.u. respectively.
- (iii) What are muons?
 $(2+3)+3+2=10$
4. (a) (i) Write Maxwell's electromagnetic equations and discuss their physical significances.
- (ii) Discuss the elementary idea of holography. Also mention two uses of holography.
 $(2+4)+(3+1)=10$

14M-790/869

(Turn Over)

Or

- (b) (i) Explain the terms spontaneous emission and stimulated emission. Hence derive the expressions for Einstein's A and B coefficients.
- (ii) Briefly discuss Hertz's experiment. $(1\frac{1}{2} + 1\frac{1}{2} + 4) + 3 = 10$

- 5. (a) (i) State De Morgan's theorem. Verify De Morgan's theorem by using 3-input gate truth table.

(ii) Prove that

$$\overline{AB} + \overline{A} + \overline{AB} = 0 \text{ and}$$

$$\overline{ABC(A+B+C)} = \overline{ABC} \quad (2+3) + (2\frac{1}{2} + 2\frac{1}{2}) = 10$$

Or

$(\overline{A} + \overline{B} + \overline{C}) \cdot (\overline{A} \cdot \overline{B} \cdot \overline{C})$
 $= \overline{A} \cdot \overline{B} \cdot \overline{C} + \overline{A} \cdot \overline{B} \cdot C + \overline{A} \cdot B \cdot \overline{C} + A \cdot \overline{B} \cdot \overline{C}$
 $= \overline{A} \cdot \overline{B} \cdot \overline{C} + \overline{A} \cdot \overline{B} \cdot C + \overline{A} \cdot B \cdot \overline{C} + A \cdot \overline{B} \cdot \overline{C}$

- (i) Write a BASIC program to find the solution of the quadratic equation $ax^2 + bx + c = 0$, where a, b and c are given as input.

- (ii) Show that both NAND gate and NOR gate are universal gates. $4 + (3+3) = 10$

- 6. (a) (i) Discuss the failure of classical theory in explaining black-body radiation phenomenon.

- (ii) Derive Planck's energy distribution law of black-body radiation. $4+6=10$

Or

- (b) (i) State and explain Heisenberg's time-energy uncertainty principle.
- (ii) How can you illustrate Heisenberg's uncertainty principle experimentally?
- (iii) Why is de Broglie hypothesis not applicable in macroscopic world? $3+5+2=10$

- 7. (a) (i) Derive the time dependent Schrödinger equation from the idea of quantum mechanical operators and hence solve it by the method of separation of variables.

- (ii) Show that Hermitian operators always have real eigenvalues. $7+3=10$

Or

- (b) (i) What do you mean by a free particle? Solve the Schrödinger's wave equation for a particle confined in a one-dimensional box.

- (ii) What is zero-point energy?

- (iii) Mention the physical significance of wave function. $(1+5)+2+2=10$