3 (Sem–5) PHY M 1

2021

(Held in 2022)

PHYSICS

(Major)

Paper : 5·1

Full Marks : 60

Time : Three hours

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

GROUP–A

(Mathematical Methods)

Marks : 30

1. Answer the following questions : 1×4=4

(a) State de Moivre's theorem.

(b) Obtain the modulus of the complex number $\frac{1-i}{1+i}$.

(c) Define pole and residue.

(d) What does the equation $|z-i|=2$ represent ?

2. (a) Give the graphical representation of complex variable through Argand diagram. 2

(b) Check the analyticity of the function $f(z)=\log z$. 2

(c) Obtain the Laurent expansion of the function $f(z)=\frac{1}{z(z-1)}$ about $z=0$. 2

3. (a) State and prove Cauchy-Riemann conditions for analytical functions. 1+4=5

(b) Using residue theorem, evaluate

$$\int_0^{2\pi} \frac{d\theta}{5+4\cos\theta}.$$ 5

Or

(a) Establish Cauchy's integral theorem for an analytic function $f(z)$,

$$\oint_C f(z)\,dz = 0$$

around a closed path. 7

(b) Obtain Taylor series expansion of the function $f(x)=e^x$ around the point $x=0$. 3

4. (a) Locate the places of the complex function $f(z)=\frac{1}{z^2+1}$ and obtain the residues. Use them to establish the relation

$$\int_{-\infty}^{+\infty} \frac{dx}{1+x^2} = \pi.$$ 2+2+2=6

(b) (i) If $f(z) = e^z = e^{x+iy}$, find the maximum amplitude of $f(z)$. 1

(ii) Expand $log(a+z)$ about a, where

$$log(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \ldots\ldots$$ 3

Or

Evaluate the following integrals by contour integration : 5+5=10

(i) $$\int_{-\infty}^{+\infty} \frac{\sin x}{x} dx$$

(ii) $$\int_{0}^{\infty} \frac{1-\cos x}{x^2}$$

GROUP–B

(Classical Mechanics)

Marks : 30

5. Answer the following questions : 1×4=4

   (a) Define central force and write down a general expression for it.

   (b) State the principle of virtual work.

   (c) What is the physical significance of the Hamiltonian of a particle ?

   (d) Mention *two* properties of Poisson bracket.

6. Answer ***any three*** of the following questions : 2×3=6

   (a) Give the concept of reduced mass.

   (b) Show that angular momentum is a constant of central force motion.

   (c) Prove that if Hamiltonian H is not an explicit function of time t, then H is a constant of the motion.

(d) Explain generalised coordinate.

7. Answer ***any three*** of the following questions : 4×3=12

(a) Show that a two-body central force problem can be reduced to one-body problem.

(b) Establish the condition when the orbit of a particle under a central force becomes an ellipse.

(c) Set up Lagrangian equation for an Atwood machine and find an expression for its acceleration.

(d) Establish d'Alembert's principle in terms of generalised coordinates.

(e) Find the equation of motion of a system with the given Lagrangian

$$L = \frac{1}{2} e^{\alpha t} \left(\dot{x}^2 - \omega^2 x^2 \right)$$

where α and ω are constants.

8. What is Hamilton's variational principle ? Use it to deduce the Lagrange's equation of motion in terms of Lagrangian $L(q_i, \dot{q}_i; t)$. 2+6=8

Or

Define Hamiltonian of a system and establish Hamilton's canonical equation. 1+7=8

2021

(Held in 2022)

PHYSICS

(Major)

Paper : 5·2

(Atomic Physics)

Full Marks : 60

Time : Three hours

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

1. Choose the correct option : 1×7=7

(a) Rutherford's α particle scattering experiment gave experimental information about

(i) the charge of the α particle

(ii) the size of the atom

(iii) the size of the nucleus

(iv) None of the above

(b) The minimum number of electrons in a sub-shell with orbital angular momentum quantum number l is

(i) $2(2l+1)$

(ii) $2(2l-1)$

(iii) $(2l+1)$

(iv) $(2l-1)$

(c) The splitting of spectral lines with components in strong electric field is known as

(i) normal Zeeman effect

(ii) anomalous Zeeman effect

(iii) Paschen-Back effect

(iv) Stark effect

(d) The electron of H-atom is excited to the n-th orbit. Then the total number of emission lines in the spectrum will be

(i) $1/2n(n-1)$

(ii) $1/2n(n+1)$

(iii) $n(n-1)$

(iv) $n(n+1)$

(e) The electron revolves around the nucleus of the hydrogen atom in second excited state. The angular momentum of the electron is

(i) $h/2\pi$

(ii) h/π

(iii) $3h/2\pi$

(iv) 0

(f) The frequency of whose spectral series of hydrogen atom lies in the visible region ?

(i) Lyman series

(ii) Balmer series

(iii) Paschen series

(iv) Bracket series

(g) Rotational spectra are always obtained in

(i) emission

(ii) absorption

(iii) dispersion

(iv) deviation

2. Answer ***any four*** of the following : $2\times4=8$

(a) The energy of a hydrogen atom in its ground state is -13.6 *eV*. Find the K.E and potential energy of the electron in this state.

(b) Calculate the closest distance of approach of an α particle of energy 5 *MeV* shot at a gold nucleus.

(c) A charged oil drop is suspended in an uniform electric field of 3×10^4 V/m so that it neither rises nor falls. If the mass of the drop is 9.75×10^{-15} kg, find the charge on the drop.

(d) Using vector atom model, determine the possible values of the total angular momentum of an f electron ($l = 3$).

(e) What is space quantization ? Explain briefly.

(f) State and explain Mosley's law.

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

(a) Describe the improvement made by Sommerfeld in Bohr's atomic model. How could it explain the fine structure of hydrogen spectral lines ?

(b) Explain L-S and j-j coupling.

(c) Explain the continuous and characteristic spectra of X-rays.

(d) Explain the theory of Bainbridge's mass spectrograph to detect isotopes of an element.

(e) Differentiate between Zeeman effect and Paschen-Back effect.

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

(a) Draw a neat and labelled diagram of the apparatus used by Thomson for determination of q/M of positive rays. Show mathematically that positive ions with the same q/M value trace out a parabola. Explain how the mass of an isotope can be determined from the parabolic traces. 2+6+2=10

(b) Draw a neat diagram of the experimental arrangement of Stern and Gerlach. What effect the magnetic field would have produced had it been uniform? Show how two traces are produced by the atomic beam. 3+2+5=10

(c) What is Compton effect? Derive an expression for the change in wavelength of a photon when it is scattered by an electron. Justify the importance of its theory. 2+5+3=10

(d) What are the characteristics of Raman effect? Discuss the theoretical explanation of Raman effect. Write the experimental method to obtain Raman spectrum. 3+5+2=10

(e) Explain the meaning of different quantum numbers which specify the state of an electron in the vector atom model. State that at any state of principal quantum number n, the maximum number of electron which can be accommodated is $2n^2$. Write down the electronic configuration of Cu ($Z = 29$). 3+2+2+3=10

3 (Sem–5) PHY M 3

2021

(Held in 2022)

PHYSICS

(Major)

Paper : 5·3

Full Marks : 60

Time : Three hours

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

GROUP–A

(Quantum Mechanics)

Marks : 40

1. Answer ***any four*** of the following as directed : 1×4=4

(a) The probability of finding a particle represented by $\psi(\vec{r}, t)$ in unit volume is

(i) $|\psi(\vec{r}, t)|$

(ii) $|\psi(\vec{r}, t)|^2$

(iii) $|\psi(\vec{r}, t)|^3$

(iv) $\psi(\vec{r}, t)$

(Select the correct answer)

(b) Which statement is correct ?

(i) Group velocity (v_g) = Phase velocity (v_p)

(ii) $v_g > v_p$

(iii) $v_p > v_g$

(iv) $v_p = \frac{1}{v_g}$

(c) What is the ground-state energy of a linear harmonic oscillator ?

(d) What is quantum mechanical tunnelling ?

(e) What is the total number of energy level for n th state of hydrogen atom ?

2. Answer ***any three*** questions : 2×3=6

(a) A beam of short wavelength gives accurately the position of a particle. Justify.

(b) Write the physical significance of wave function ψ and $|\psi|^2$.

(c) What is momentum operator ? Write its expectation value.

(d) Discuss the wave mechanics of the electron in a hydrogen atom in a spherical potential.

(e) Draw the wave function of a particle in a box of infinite depth.

3. Answer ***any two*** questions : 5×2=10

(a) State and explain the complementary principle of Niels Bohr. What conclusion can be drawn from the result of γ-ray microscope experiment ? 3+2=5

(b) (i) What is one-dimensional potential step ? 1

(ii) A particle of mass 'm' is moving in one-dimensional potential given by

$$V = 0 \quad for \quad x < 0$$
$$= V_0 \quad for \quad x \geq 0$$

If the total energy of the incident particle $E > V_0$, then calculate the co-efficient of reflection and transmission. 2+2=4

(c) Briefly discuss G. P. Thomson's experiment of electron diffraction, and its significance for quantum theory. 5

3. Answer ***any two*** questions : 5×2=10

(a) State and explain the complementary principle of Niels Bohr. What conclusion can be drawn from the result of γ-ray microscope experiment ? 3+2=5

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If the total energy of the incident particle $E > V_0$, then calculate the co-efficient of reflection and transmission. 2+2=4

(c) Briefly discuss G. P. Thomson's experiment of electron diffraction, and its significance for quantum theory. 5

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

(a) (i) What is the need for normalization of a wave function ? Calculate the normalization constant of a wave function (at $t = 0$) given by

$$\psi(x) = a e^{-\left(a^2x^2/2\right)} . e^{ikx}$$

Hence determine the probability current density of the wave function. 2+2+3=7

(ii) Establish the relation :

$[L_x, L_y] = i\hbar L_z$; $[L^2, L_z] = 0$, where the notations have usual meanings. 3

(b) (i) The radial part of wave function for hydrogen in the ground state is given by $R = \frac{2}{a_0^{3/2}} . e^{-r/a_0}$. Find an expression for ground state energy of hydrogen atom ($n = 1$, $l = 0$). 6

(ii) Deduce the relation between phase velocity and group velocity for the de Broglie waves. Which of these two is associated with particle velocity. 3+1=4

(c) Write the potential for one-dimensional harmonic oscillator and use it to build up a time-independent Schrödinger's wave equation. Solve the equation for its energy eigenvalues. 1+2+7=10

(d) (i) State Heisenberg's uncertainty principle and derive it from a hypothetical gamma ray microscope. 1+6=7

(ii) A proton and a deutron having the same energy penetrate a given rectangular barrier. Which particle has greater depth of penetration ? 3

GROUP–B

(Astrophysics)

Marks : 20

5. Answer ***any three*** from the following : 2×3=6

(a) Define ecliptic. What are vernal equinox and right ascension ?

(b) What do you mean by colour index ? What is the declination (δ) at celestial pole and celestial equator ?

(c) Write the potential for one-dimensional harmonic oscillator and use it to build up a time-independent Schrödinger's wave equation. Solve the equation for its energy eigenvalues. 1+2+7=10

(d) (i) State Heisenberg's uncertainty principle and derive it from a hypothetical gamma ray microscope. 1+6=7

(ii) A proton and a deutron having the same energy penetrate a given rectangular barrier. Which particle has greater depth of penetration ? 3

GROUP–B

(Astrophysics)

Marks : 20

5. Answer ***any three*** from the following : 2×3=6

(a) Define ecliptic. What are vernal equinox and right ascension ?

(b) What do you mean by colour index ? What is the declination (δ) at celestial pole and celestial equator ?

(c) Define the absolute magnitude and distance modulus of a star.

(d) What is parsec ? Determine the distance to the star 'vega' whose parallax is $0''.123$.

(e) Derive the relation between the intensity ratio and magnitude difference between two stars.

6. Answer ***any two*** of the following : 4×2=8

(a) Discuss the method of trigonometric parallex to determine stellar distances. Mention the limitation of this method.

(b) What is H-R diagram ? How can the evaluations of various celestial objects be described in terms of H-R diagram ?

(c) The sun has an apparent magnitude $m = -26^m.5$. Calculate its absolute magnitude.

7. Write short notes on ***any two*** of the following : 3×2=6

(a) Protostar and its formation

(b) Sidereal time

(c) White dwarfs

(d) H-D classification of stars

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3 (Sem–5) PHY M4

2021

(Held in 2022)

PHYSICS

(Major)

Paper : 5·4

(Electronics)

Full Marks : 60

Time : Three hours

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

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

   (a) What is dark current of a photodiode ?

   (b) Give the statement of maximum power transfer theorem when an energy source delivers power to a load impedance.

(c) What types of biasing are necessary for 'transistor' action ?

(d) Mention *two* basic conditions for oscillations in a feedback amplifier.

(e) Write the expression for common mode rejection ratio (CMRR) in *dB*.

(f) What is the cut-off frequency beyond which the ionosphere does not reflect electromagnetic waves ?

(g) What is meant by race-around condition in a flip-flop ?

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

(a) What is the need of stabilization of Q-point of a transistor amplifier ?

(b) Draw the logic symbol diagrams to convert J-K flip-flop to D and T flip-flops.

(c) What are the basic units of a regulated power supply system?

(d) Give the circuit diagram of an OPAM as an integrator.

3. Draw the circuit diagram of a full-wave rectifier with resistive load. Derive the expression for its efficiency. 2+3=5

Or

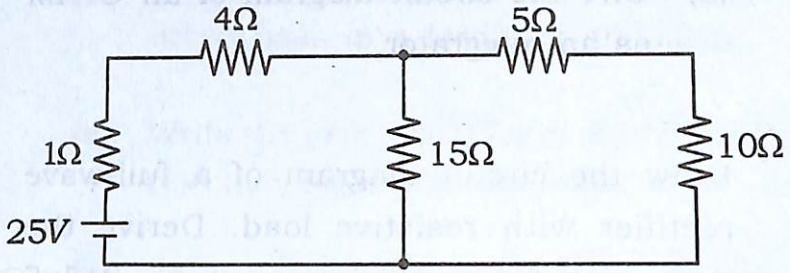
Differentiate between class A, class B and class C amplifiers with diagrams. 5

4. Draw the circuit diagram of Weinbridge oscillator. Mention the expression for the frequency of oscillation. 4+1=5

Or

Write down the characteristics of an ideal OPAM. 5

5. Using Norton's theorem, find the current through resistance 10Ω of the following circuit :



Also draw the equivalent circuit. 5

6. Answer ***any two*** questions from the following : 5×2=10

(a) Why are NAND and NOR gates called universal gates ? Give the truth table of NOR gate. Draw diagrams to show how OR, NOT and NOT gates can be realized using NOR gates only.

1+1+3=5

(b) Draw the circuit diagram of a super-heterodyne receiver. What is the main advantage of a superheterodyne receiver over others ?

3+2=5

(c) Derive the expressions for overall current gain and overall voltage gain of a CE transistor amplifier using *h*-parameter equivalent circuit. 5

(d) What is the frequency range of radio waves ? Discuss different ways of radio wave propagation mentioning appropriate frequency range and approximate distance between the transmitting and receiving antenna. 5

7. Answer ***any two*** questions from the following : 5×2=10

(a) What is amplitude modulation ? Show that in amplitude modulation two sidebands are equispaced with respect to carrier frequency. 1+4=5

(b) State and prove maximum power transfer theorem. 1+4=5

(c) Define positive and negative feedback. Draw the block diagram of a feedback amplifier and find an expression for overall gain of such an amplifier. 1+2+2=5

(d) Draw the circuit diagram of a two-stage R-C coupled amplifier. Also calculate the expression for voltage gain in the mid-frequency range. 2+3=5

8. Answer ***any two*** questions from the following : 5×2=10

(a) Convert the decimal numbers 45·50 and 13·25 to its binary equivalent and find the difference using 2's complement method. 2+3=5

(b) Draw the circuit diagram of a class-B push-pull power amplifier and derive an expression for its efficiency. 2+3=5

(c) What are clipping and clamping circuits ? Draw circuit diagrams of both the circuits with output waveforms. 1+2+2=5

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

(i) RS flip-flop

(ii) Microprocessor

(iii) Zener diode