3 (Sem–4/CBCS) PHY HC 1

2022

PHYSICS

(Honours)

Paper : PHY–HC–4016

(Mathematical Physics–III)

Full Marks : 60

Time : Three hours

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

1. Answer ***any seven*** questions of the following : 1×7=7

   (a) What is the argument of $-3i$?

   (b) Express $f(z)=z^2$ in the form of $u(x, y)+iv(x, y)$.

   (c) What is singular point of an analytic function ?

(d) Evaluate $\delta_q^p A_s^{qr}$.

(e) State the shifting property of Fourier transform (FT).

(f) Find the residue of the complex function $f(z)=\frac{1}{z^2+1}$ at the pole $z=i$.

(g) Show that $L(1)=\frac{1}{s}, s>0$.

(h) What is rank of a tensor? Give *one* example of a zero rank tensor.

(i) Define Fourier inverse transform.

(j) Write the polar form of a complex number.

2. Answer ***any four*** of the following questions : 2×4=8

(a) Check whether the function *log z* is analytic or not.

(b) Plot the complex number $e^{(1-\pi/6i)}$ in Argand diagram.

(c) Prove that the contraction of the tensor A_m^l is invariant.

(d) Obtain the Fourier transform of the function

$$f(x)=\begin{cases} x, & 0<x<1 \\ 0, & \text{otherwise} \end{cases}$$

(e) Using the property of Levi-Civita symbol prove that $\vec{A}\times\vec{B}=-(\vec{B}\times\vec{A})$.

(f) If $L[f(x)]=\bar{f}(s)$, then show that $L\left|e^{ax}f(x)\right|=\bar{f}(s-a)$.

(g) Evaluate the integral $\oint\frac{dz}{z}$ around a unit circle.

(h) Expand the function

$f(z)=\frac{1}{z+1}$, about $z=1$ in Taylor series up to two terms.

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

(i) Find the value of the integral $\int_0^{1+i} (x - y - ix^2)\,dz$, along real axis from $z = 0$ to $z = 1$ and then along the line parallel to imaginary axis from $z = 1$ to $z = 1 + i$.

(ii) State and prove Cauchy's integral formula.

(iii) Obtain the Fourier sine and cosine transform of the function

$$f(x) = \begin{cases} 1, & 0 < x < \pi/2 \\ 0, & x > \pi/2 \end{cases}$$

(iv) What is Kronecker delta? Show that it is a mixed tensor of rank 2. 2+3=5

(v) Find the Laplace transform of the function $f(t) = \sin at$.

(vi) Show that $|z_1 \cdot z_2| = |z_1| \cdot |z_2|$ and $Arg(z_1 \cdot z_2) = Arg(z_1) + Arg(z_2)$.

(vii) What are raising and lowering of indices of a tensor? Prove that the raising and lowering operation of indices are reciprocal to each other. 2+3=5

(viii) Evaluate $\oint_C \frac{\cos z}{z}\,dz$, where C is an ellipse given by $9x^2 + 4y^2 = 1$, using Cauchy's integral formula. 5

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

(a) (i) Show that if $f(z) = u + iv$ is an analytic function and $\vec{F} = \hat{i}v + \hat{j}u$ is a vector, then $div\,\vec{F} = 0$ and $curl\,\vec{F} = 0$ are equivalent to Cauchy-Reimann equations. 6

(ii) State and prove quotient law of tensors. 4

(b) (i) The Laplace transform of $\sin 3t$ is $\frac{3}{S^2 + 9}$ and the Laplace transform of $\cos 5t$ is $\frac{S}{S^2 + 25}$. Find the Laplace transform of $5\sin 3t + 3\cos 5t$ using linearity property of Laplace transform. 5

(ii) Find the inverse Laplace transform of $\frac{4S+5}{(S-1)^2(S+2)}$. 5

(c) (i) If A_λ is a covariant tensor of rank 1, show that $\frac{\partial A_\lambda}{\partial x_\mu}$ is not a tensor. 3

(ii) Prove the following identities : 2+2+3=7

(a) $\delta_{ii} = 3$

(b) $\delta_{ik}\varepsilon_{ikm} = 0$

(c) $\varepsilon_{iks}\varepsilon_{mps} = \delta_{im}\delta_{kp} - \delta_{ip}\delta_{km} = 0$

(d) State and prove Fourier integral theorem.

(e) (i) Using the method of residues, show that $\int_0^\infty \frac{dx}{x^4+1} = \frac{\pi\sqrt{2}}{4}$. 6

(ii) Express the complex number $1+2i/1-3i$ in $r(\cos\theta + i\sin\theta)$ form. 4

(f) Evaluate ***any two*** of the following integrals by contour integration : 5×2=10

(i) $\int_0^\infty \frac{dx}{x^2+1}$

(ii) $\int_{-\infty}^{\infty} \frac{\sin x}{x}\,dx$

(iii) $\int_{-\infty}^{+\infty} \frac{e^{ax}}{1+e^x}\,dx$

(g) Solve the wave equation $\frac{\partial^2 y}{\partial t^2} = c^2\frac{\partial^2 y}{\partial x^2}$ under the conditions that, $y(x,0)=0$, $y'(x,0)=0, x>0$ and $y(0,t)=t$, $\lim_{x\to\infty} y(x,t)=0, t\geq 0$.

(h) (i) What is residue of a complex function? State and prove Cauchy's residue theorem. 1+1+4=6

(ii) Show that any contravariant or covariant tensor of the second order can be resolved into symmetric and antisymmetric parts. 4

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3 (Sem–4/CBCS) PHY HC2

2022

PHYSICS

(Honours)

Paper : PHY–HC–4026

(Elements of Modern Physics)

Full Marks : 60

Time : Three hours

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

1. Answer ***any seven*** questions of the following : 1×7=7

   (a) What is the rest mass of photon ?

   (b) Define work function in the phenomenon of photoelectric effect.

(c) What is confirmed by Davisson and Germer experiment?

(d) What is wave particle duality?

(e) What is quantum dot?

(f) The volume of 80^{16} nucleus is V. What is the volume of $_{29}Cu^{64}$ nucleus?

(g) Write the relation between half life and mean life.

(h) At what energy range, gamma photon shows the Compton effect?

(i) What is the main source of solar energy?

(j) What is pumping in LASER technology?

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

(a) What is virtual particle?

(b) Explain eigenfunction and eigenvalues of an operator.

(c) Show that nuclear density is independent of the mass number.

(d) Write *two* properties of nuclear force.

(e) If the half life of a radioactive substance is 15 seconds, calculate its decay constant.

(f) Calculate the energy released from the fission of $10gm\ U^{235}$. [Energy per fission is $200MeV$]

(g) Write *two* properties of LASER.

(h) Write *two* necessary conditions for nuclear fusion reaction.

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

(a) Derive the one-dimensional time dependent Schrödinger equation for a moving free particle.

(b) Find the expression of momentum operator.

(c) Discuss the magic number in the context of nuclear shell model.

(d) State the law of radioactivity and derive it mathematically. 2+3=5

(e) Explain the fine structure of α decay.

(f) Write a short note on pair production process.

(g) What is nuclear fission reactor? Describe the main parts of a nuclear reactor. 1+4=5

(h) Explain the following :

(i) Spontaneous emission

(ii) Stimulated emission

(iii) Metastable states

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

(a) What is Compton scattering? Explain the experimental arrangement of Compton scattering. Derive the expression of Compton shift. 1+3+6=10

(b) State Heisenberg uncertainty principle. Derive this principle from wave packets. 2+8=10

(c) A particle of mass m is confined in a one-dimensional infinitely rigid box of length L. The potential function is given by

$$V(x) = \alpha, \quad x \leq 0$$
$$= 0, \quad 0 < x < L$$
$$= \alpha, \quad x \geq L$$

(i) Find the wave function of the particle inside the box.

(ii) Find the expression of energy eigenvalues. 6+4=10

(d) Derive the expression of transmission coefficient and reflection coefficient, when a particle of mass m, kinetic energy E is incident on a one-dimensional potential barrier, if the kinetic energy is greater than the potential of the barrier. 5+5=10

(e) Derive the expression of semi-empirical mass formula and explain each term involved in this expression. 6+4=10

(f) Explain the continuous beta decay spectrum. What are the difficulties in interpreting this continuous spectrum? How did Pauli resolve these difficulties? 3+4+3=10

(g) Explain the construction and different operating regions of a gas-filled detector. 3+7=10

(h) Describe the construction and working of Ruby LASER. Mention *two* applications of Ruby LASER. (4+4)+2=10

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3 (Sem–4/CBCS) PHY HC 3

2022

PHYSICS

(Honours)

Paper : PHY–HC–4036

(Analog Systems and Applications)

Full Marks : 60

Time : Three hours

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

1. Answer ***any seven*** questions from the following : 1×7=7

   (i) Resistivity of a semiconductor _____ with increase in temperature.
   (Fill in the blank)

   (ii) Potential barrier across a p-n junction diode is due to accumulation of
   (a) electrons
   (b) opposite ions
   (c) space charges
   (d) holes *(Choose the correct option)*

(iii) Class-C amplifier produces the least efficiency but exhibits good linearity.
*(Write True **or** False)*

(iv) RC-coupled amplifier is used for
(a) current amplification
(b) power amplification
(c) voltage amplification
(d) None of the above
(Choose the correct option)

(v) In a transistor amplifier, lower value of the stability factor indicates the better stability of the quiescent point.
*(Write True **or** False)*

(vi) Bandwidth of an amplifier increases by employing
(a) positive feedback
(b) all types of negative feedback
(c) current-series positive feedback
(d) voltage-series negative feedback
(Choose the correct option)

(vii) In an op-amp the input stage is usually a _____ amplifier.
(Fill in the blank)

(viii) If a sine wave is applied to the input of an op-amp differentiator circuit, the output would be a
(a) cosine wave
(b) triangular wave
(c) square wave
(d) pulse *(Choose the correct option)*

(ix) Wien bridge oscillator is an audio frequency sine wave oscillator of high _____.
(Fill in the blank)

(x) Resolution of a DAC is equal to the weight of
(a) LSB
(b) MSB
(c) 1 V
(d) 15 V *(Choose the correct option)*

2. Answer ***any four*** questions : 2×4=8

(i) What is ripple factor ? What is the value of ripple factor of a half-wave rectifier ?

(ii) The current amplification factor of a transistor in common emitter configuration is $\beta = 30$. Calculate collector current I_C and emitter current I_E if the base current is $I_B = 10\ \mu A$.

(iii) What is positive feedback? Why is positive feedback most commonly used in oscillator?

(iv) Define CMRR of an op-amp. Express it in dB form.

(v) In a non-inverting op-amp with $R_1 = 1k\Omega$ and $R_F = 100k\Omega$, find the closed-loop voltage gain of the op-amp.

(vi) Draw the circuit diagram of a two-stage RC-coupled transistor CE amplifier.

(vii) Write the applications of Hartley and Colpitt oscillators.

(viii) What are the advantages of R-2R ladder DAC over weighted-resistor DAC?

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

(i) A full-wave rectifier with an applied voltage of $400 \sin \omega t$ is centre-tapped with a load resistance of $2k\Omega$. If the resistance of the diodes are 100 Ω each, determine *(a)* peak value of current, *(b)* dc value of output current in the load, and *(c)* rectification efficiency of the rectifier. 1+2+2=5

(ii) What do you mean by class A, class B and class C amplifiers? Why is the efficiency of class B amplifier more than that of class A amplifier? 3+2=5

(iii) Derive the expression for the voltage gain of RC-coupled transistor amplifier for mid-frequency range.

(iv) Explain how an op-amp can be used as (i) a differentiator, and (ii) an integrator.

(v) Find the operating frequency of a Hartley oscillator if $L_1 = 10\mu H$, mutual inductance between the coils $M = 15\mu H$, $L_2 = 2mH$ and $C = 10\mu F$. Find also the hFE value for sustained oscillations.

(vi) Define common-base current amplification factor (α) and common emitter current amplification factor (β). Derive the relation between α and β. 2+3=5

(vii) The total linear distortion of an amplifier is reduced from 10% to 2% when 4% negative feedback is applied. Find voltage gain of the amplifier without feedback and with feedback.

(viii) Write short notes on :

(a) Photodiode

(b) Light emitting diode

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

(i) What are drift current and diffusion current in a semiconductor ? How are the potential barrier and depletion region formed in a p-n junction ? Derive the p-n diode equation for determining the current through the junction. 2+2+6=10

(ii) Distinguish between Zener diode and ordinary p-n junction diode. Explain the action of Zener diode as voltage regulator with circuit diagram. Draw the V-I characteristic curve of a Zener diode. 2+6+2=10

(iii) Draw the *h*-parameter equivalent circuit of a CE transistor amplifier and derive the expressions for its current gain, voltage gain, input impedance and power gain. 2+2+2+2+2=10

(iv) What is transistor biasing ? Discuss the fixed bias and self bias methods of transistor biasing. Calculate the stability factor of a fixed bias method. What are the disadvantages of a fixed bias method ? 1+(3+3)+2+1=10

(v) What is negative feedback ? Discuss the effect of negative feedback on *(a)* input impedance, *(b)* output impedance, *(c)* non-linear distortion, and *(d)* noise of an amplifier. 2+(2+2+2+2)=10

(vi) Draw the circuit diagram of an RC-phase shift oscillator and explain its operation. Find an expression for the frequency of oscillations and the condition of sustained oscillations. (2+2)+(4+2)=10

(vii) What are inverting and non-inverting op-amps? With the help of a circuit diagram describe the inverting op-amp with feedback. Derive the expression for the closed loop voltage gain of this amplifier. What do you mean by virtual ground in this op-amp?

2+3+3+2=10

(viii) With the help of a neat diagram explain the working of weighted registor DAC. What are its advantages and disadvantages? Write *any two* major applications of D/A converters.

4+(2+2)+2=10
