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4 SEM TDC PHYH (CBCS) C 8

2025

(May/June)

PHYSICS

(Core)

Paper : C–8

(Mathematical Physics—III)

Full Marks : 53

Pass Marks : 21

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct answer of the following : 1×5=5

(a) The dot product of $z_1 = 3 - 4i$ and $z_2 = -4 + 3i$ is

(i) –7

(ii) –24

(iii) 24

(iv) 0

(b) The function

$$f(z)=\frac{1}{(z-2)^3}$$

has a pole at

(i) $z=0$

(ii) $z=1$

(iii) $z=2/3$

(iv) None of the above

(c) The convolution theorem states that the Fourier transform of a convolution of two functions is

(i) the product of their individual Fourier transforms

(ii) the sum of their individual Fourier transforms

(iii) the difference of their individual Fourier transforms

(iv) None of the above

(d) The change of scale property of the Fourier transform states that if a function $f(t)$ has a Fourier transform $F(\omega)$, then the Fourier transform of $f(at)$ (where $a>0$) is

(i) $\frac{1}{|a|}F\left(\frac{\omega}{a}\right)$

(ii) $|a|\,F(a\omega)$

(iii) $F\left(\frac{\omega}{a}\right)$

(iv) $\frac{1}{a}F(a\omega)$

(e) The Laplace transform of the constant function $f(t)=1$ is

(i) $\frac{1}{s}$

(ii) s

(iii) e^{-s}

(iv) $\frac{1}{s^2}$

2. Identify the poles and calculate the residues of the following functions : 2×2=4

(a) $f(z) = \dfrac{z^2 - 3}{z^2 + 7z + 12}$

(b) $f(z) = \dfrac{z}{(z-1)(z+1)^2}$

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

(a) Show that the function $f(z) = \bar{z}$ is continuous but not differentiable.

(b) Check the continuity and differentiability of the function $f(z) = z^2$.

(c) Show that $f(z) = \cos z$ is analytic in the complex plane.

4. Answer the following : 4×2=8

(a) Expand

$$f_1(z) = \frac{z}{(z+1)(z+2)}$$

in Laurent series about the pole $z = -2$.

(b) Expand $f_2(z) = \sin z$ in a Taylor series about $z = \dfrac{\pi}{4}$.

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

(a) Derive the Cauchy-Riemann equations in polar coordinates.

(b) What are the different types of singularities of a complex function? Locate and name the singularities of

$$f(z) = \frac{z^8 + z^4 + 2}{(z-1)^3 (3z+2)^2}$$

(c) Compute the integral

$$\int_0^{2\pi} \frac{d\theta}{7 + 6\cos\theta}$$

(d) Using Cauchy's integral formula show that

$$\oint_C \frac{z^2 + 3}{z - 1} dz = 8\pi i$$

6. Solve any *two* of the following problems : 5×2=10

(a) Find the Fourier transform of the function $f(x) = e^{-ax^2}$, where $a > 0$ is a constant. Use the definition of the Fourier transform :

$$F(\omega) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x) e^{i\omega x} dx$$

to compute the result.

(b) Find the Fourier transform $F(\omega)$ of the function $f(x)$, defined as

$$f(x) = \begin{cases} 1 & \text{if } |x| \le a \\ 0 & \text{if } |x| > a \end{cases}$$

(c) Find the Laplace transform of the following functions (any *one*) :

(i) $e^{-|t|}$

(ii) $e^{\frac{-r^2}{a^2}}$

where $r = \sqrt{x^2 + y^2 + z^2}$

7. Answer the following questions : $6\times2=12$

(a) Apply the Fourier transform technique to solve the one-dimensional wave equation

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

where $u(x, t)$ represents the displacement at position x and time t, and c is the wave speed.

(b) State the Cauchy's integral formula. Evaluate

$$\int_c \frac{\sin \pi z^2 + \cos \pi z^2}{(z-1)(z-2)} dz$$

where, c is the curve $|z| = 1$.

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4 SEM TDC PHYH (CBCS) C 9

2025

(May/June)

PHYSICS

(Core)

Paper : C–9

(Elements of Modern Physics)

Full Marks : 53

Pass Marks : 21

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct option from the following : 1×5=5

(a) Compton shift depends on

(i) incident radiation

(ii) scattering substance

(iii) angle of scattering

(iv) None of the above

(b) That electron cannot exist within the nucleus of atoms is understood from

(i) Bohr's atomic model

(ii) de-Broglie's hypothesis

(iii) Heisenberg's uncertainty principle

(iv) None of the above

(c) The Hamiltonian operator is expressed as

(i) $\hat{H} = -\frac{\hbar^2}{2m}\frac{\partial}{\partial x} + V(x)$

(ii) $\hat{H} = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x)$

(iii) $\hat{H} = \frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V(x)$

(iv) $\hat{H} = \frac{\hbar^2}{2m}\frac{\partial}{\partial x} + V(x)$

(d) The function of the component of a nuclear reactor called control rod is to

(i) slow down the emitted neutrons

(ii) stop the neutrons from escaping the fuel

(iii) absorbing the excess neutron and prevent explosion

(iv) None of the above

(e) The size of nucleus of an atom of mass number A is proportional to

(i) $A^{\frac{3}{4}}$

(ii) $A^{\frac{2}{3}}$

(iii) $A^{\frac{1}{3}}$

(iv) A

2. (a) What is stopping potential? Write down the Einstein's photoelectric equation. 2

(b) The wave function of a particle is given by $\psi = Ae^{i(kx-\omega t)}$. Show that probability current density $J = \frac{\hbar k A^2}{m}$, where m is the mass of the particle and A is a constant. 2

(c) Find the expectation value of linear momentum $< P_x >$ for the wave function

$$\psi(x) = \sqrt{\frac{2}{L}} \sin \frac{\pi x}{L}, \quad 0 \le x \le L$$

$$= 0 \quad , \quad \text{otherwise}$$ 2

(d) An electron is trapped in one-dimensional infinitely rigid box of length 0·2 nm. Calculate the energy required by the electron to rise from its ground state to the fourth state. 2

(e) What is quantum tunneling? Does quantum tunneling violate energy conservation? 1+1=2

(f) 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? 2

3. (a) Prove that the particle velocity is equal to the group velocity of wave packet. 3

Or

An X-ray photon of wavelength 0·2 Å is scattered at an angle 90° with its original direction after collision with an electron at rest. Calculate the change of wavelength and the loss of energy of the photon due to scattering. (Given that $h = 6 \cdot 6 \times 10^{-34}$ Js ; $m_0 = 9 \cdot 1 \times 10^{-31}$ kg and $c = 3 \times 10^8$ m/sec).

(b) Explain wave particle duality. 3

Or

Using Heisenberg's uncertainty principle, find the minimum energy of a linear harmonic oscillator.

(c) Derive the one dimensional time independent Schrödinger equation. 3

Or

If the operator

$$\left(x + \alpha \frac{d}{dx} \right)$$

has the eigenvalue λ, find the corresponding eigenfunction.

(d) Show that an electron cannot reside inside the nucleus. 3

(e) How does the nuclear fission occur? Explain nuclear fission on the basis of liquid drop model. 1+2=3

(f) Define Einstein's A and B coefficients. Why is a metastable state required for laser action? 3

4. (a) Describe the Davisson-Germer experiment. 4

(b) A particle of mass m and kinetic energy E is moving along positive X-axis towards a finite potential step. The potential function of the potential step is given by

$$V(x) = \begin{cases} 0 & \text{for } x < 0 \\ V_0 & \text{for } x > 0 \end{cases}$$

Show that for $E > V_0$ the incident particle has a finite probability of being reflected and a finite probability of being transmitted. 4

5. (a) What is the binding energy of a nucleus? Write an expression for it. How does the binding energy per nucleus explain the stability of the nucleus? 1+1+3=5

Or

Discuss the liquid drop model. 5

(b) Define half-life ($T_{\frac{1}{2}}$) and mean life (τ) of a radioactive substance. Derive the expression for $T_{\frac{1}{2}}$ from the radioactive decay law $N = N_0 e^{-\lambda t}$. 5

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4 SEM TDC PHYH (CBCS) C 10

2025

(May/June)

PHYSICS

(Core)

Paper : C–10

(Analog Systems and Applications)

Full Marks : 53

Pass Marks : 21

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct answer (any *five*) : 1×5=5

(a) When reverse bias is applied to a junction diode

(i) potential barrier decreases

(ii) potential barrier increases

(iii) majority carrier increases

(iv) minority carrier increases

(b) Diodes which are operated under reverse bias condition are

(i) Zener diode, LED

(ii) Zener diode, photodiode

(iii) photodiode, LED

(iv) All of the above

(c) To work as a linear amplifier, a transistor must operate in

(i) the active region

(ii) the saturation region

(iii) the cut-off region

(iv) None of the above

(d) In CE arrangement, the value of input impedance is approximately equal to

(i) h_{ie}

(ii) h_{oe}

(iii) h_{re}

(iv) None of the above

(e) An OP-AMP can amplify

(i) only a.c

(ii) only d.c

(iii) both a.c and d.c

(iv) neither d.c nor a.c

(f) The relation between α and β of a transistor is

(i) $\beta = \dfrac{\alpha}{1+\alpha}$

(ii) $\beta = \dfrac{\alpha}{1-\alpha}$

(iii) $\alpha = \dfrac{\beta}{\beta-1}$

(iv) $\alpha = \dfrac{\beta}{\beta+1}$

2. Answer the following : 2×5=10

(a) Define mobility of a carrier and mention its unit.

(b) Why is silicon or germanium not used to fabricate LED?

(c) What is a load line in a transistor characteristics?

(d) What are class A and class B amplifiers?

(e) Define CMRR and slew rate of an OP-AMP.

3. (a) Explain the formation of barrier potential in a p-n junction. Derive an expression for the barrier potential of a p-n junction. 4

Or

Draw the energy band diagrams of n-type and p-type semiconductors indicating the position of Fermi level. What is the position of Fermi level of an intrinsic semiconductor?

(b) Draw the circuit diagram of a full-wave rectifier and calculate its ripple factor. 4

Or

Write about working and construction of photodiode. How does it differ from solar cell?

4. Explain with necessary diagram, the mechanism of current flow in an n-p-n transistor. 3

Or

A transistor is connected in common base configuration. If $I_C = 1{\cdot}9$ mA and $I_B = 0{\cdot}05$ mA, find the current amplification factor in common-base and common-emitter connection of the amplifier (α and β, respectively).

5. (a) Draw the small signal hybrid equivalent circuit of a basic transistor amplifier. Write the expressions for its voltage, current and power gain and input resistance of a CE transistor amplifier. 2+2=4

(b) A CE transistor amplifier is connected with a load resistance 2 kΩ. If the h-parameters of the transistor are

$h_{ie} = 1000\ \Omega$, $h_{re} = 10^{-4}$, $h_{fe} = 100$ and $h_{oe} = 12 \times 10^{-6}$ S, find the current gain. 2

6\. (a) Explain the operation of a two-stage RC coupled CE transistor amplifier with a neat circuit diagram. 2+2=4

(b) What is negative feedback? Explain with necessary frequency response curve, how the bandwidth of an RC coupled amplifier is modified when negative feedback is used. 1+2=3

(c) Draw the block diagram of an oscillator showing the essential parts of a practical oscillator. 2

7\. (a) Draw the basic inverting amplifier with an input resistance R_1 and a feedback resistance R_f. Assuming the OP-AMP to be ideal, write the expression for the voltage gain of the inverting amplifier. 2+1=3

(b) Explain how an OP-AMP can be used as *(i)* an adder and *(ii)* a subtractor. 3

(c) Describe the use of an operational amplifier as differentiator. 3

8\. What is the function of a DAC? Write the advantage of the *R*-2*R* ladder type DAC over the weighted-resistor type DAC. 1+2=3

Or

Explain the working of a binary weighted resistor network. 3

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