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*This question paper contains 4 printed pages.*

Your Roll No. ....11/5718.....

S. No. of Paper : 6682 HC  
Unique Paper Code : 32221401  
Name of the Paper : **Mathematical Physics - III**  
Name of the Course : **B.Sc. (Hons.) Physics**  
Semester : IV  
Duration : **3 hours**  
Maximum Marks : 75



*(Write your Roll No. on the top immediately)*

*on receipt of this question paper.)*

*All questions carry equal marks*

*Question no. 1 is compulsory*

*Attempt 2 questions from Section A and 2 questions from Section B.*

*Use of Scientific Calculators is allowed.*

1. Attempt any **five** questions:

(3x5 =15)

(a) Evaluate  $(-27i)^{\frac{1}{3}}$

(b) Locate and name the singularities in the finite  $z$  plane of the function

$$f(z) = \frac{\ln(z + 3i)}{z^2}$$

(c) Evaluate  $\oint_C \frac{z^2 - z + 1}{z - 2} dz$  over a circle  $C$  in the positive sense.  $C$  is described by  $|z| = \frac{1}{2}$ .

(d) Test the analyticity of the function  $f(z) = z^2$ .

(e) Show that  $\delta(ax) = \frac{\delta(x)}{|a|}$  where  $\delta(x)$  is the Dirac Delta function and  $a$  is a constant.

(f) If  $F(\omega)$  represents the Fourier transform of  $f(t)$ , then prove that the Fourier transform of  $f(t) \cos at = \frac{1}{2} [F(\omega - a) + F(\omega + a)]$ .

(g) Evaluate the Laplace transform of  $f(t) = \cos^2 2t$

(h) Determine the inverse Laplace transform of:

$$F(s) = \left\{ \frac{e^{-2s}}{s^3} \right\}$$

### SECTION A

Attempt any two questions from this Section.

2 (a) Given a function  $v(x, y) = e^x \sin y$ . Find the function  $u(x, y)$  such that  $f(z) = u + i v$  is analytic. Express  $f(z)$  in terms of  $z$ .

(b) Prove that

$$1 + \cos 72^\circ + \cos 144^\circ + \cos 216^\circ + \cos 288^\circ = 0$$

using complex analysis. (10, 5)

3. (a) Expand  $f(z) = \sin z$  in a Taylor series about  $z = \frac{\pi}{4}$  and determine the region of convergence of this series.

(b) Find the value of the integral  $\oint_C \frac{\sin^6 z}{(z - \frac{\pi}{6})^3} dz$  over a circle  $C$  (in the positive sense) represented by  $|z| = 1$ .

(10, 5)

4. Using the method of contour integration prove any two of the following:

(a)  $\int_0^\infty \frac{dx}{x^2 + 1} = \frac{\pi \sqrt{2}}{4}$

(b)  $\int_0^{2\pi} \frac{\cos 2\theta}{5 + 4 \cos \theta} d\theta = \frac{\pi}{6}$

(c)  $\int_0^\infty \frac{\cos mx}{x^2 + 1} dx = \frac{\pi}{2} e^{-m}, m > 0$  ( $7\frac{1}{2}, 7\frac{1}{2}$ )

### SECTION B

Attempt any two questions from this Section.

5 (a) Prove that the Fourier transform of a Gaussian function ( $e^{-x^2}$ ) is also a Gaussian function.

(b) Solve the one dimensional wave equation

$$\frac{\partial^2 u(x, t)}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 u(x, t)}{\partial t^2}$$

for  $t > 0, -\infty < x < \infty$ .

$u(x, 0) = f(x); u_t(x, 0) = 0$ ; where  $u_t = \frac{\partial u}{\partial t}$  and  $v$  is the velocity of the wave. (5, 10)

6 (a) Verify the convolution theorem (Fourier transform) for

$$f(t) = g(t) = \begin{cases} 1, & |t| \leq 1 \\ 0, & |t| > 1 \end{cases}$$

(b) Given that  $\mathcal{L}^{-1}\left\{\frac{s}{(s^2+1)^2}\right\} = \frac{t \sin t}{2}$ , determine  $\mathcal{L}^{-1}\left\{\frac{1}{(s^2+1)^2}\right\}$ , where the symbol  $\mathcal{L}^{-1}$  represents the inverse Laplace transform operator. (10, 5)

7. (a) A semi-infinite rod ( $x > 0$ ) is initially at temperature zero. At time  $t = 0$ , a constant temperature  $T_0 > 0$  is applied and maintained at the face  $x = 0$ . Using Laplace transform, find the temperature at any point of the rod at any later time  $t > 0$ .

$$\left[ \text{Given, } L^{-1}\left(\frac{e^{-x\sqrt{s/k}}}{s}\right) = \text{erfc}\left(\frac{x}{2\sqrt{kt}}\right) \right]$$

(b) Using Laplace transform, prove that,

$$\int_0^{\infty} \frac{\cos 6t - \cos 4t}{t} dt = \ln \frac{2}{3}$$

(10, 5)

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Your Roll No. .... 1815118

S. No. of Paper : 6683 HC  
Unique paper code : 32221402  
Name of the paper : Elements of Modern Physics  
Name of course : B.Sc.(Hons.) Physics  
Semester : IV  
Duration : 3 hours  
Maximum marks : 75



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*Attempt five questions in all.  
Question number 1 is compulsory.  
(Symbols have their usual meaning.)*

1. Answer any five of the following:  $5 \times 3 = 15$

- Under favourable conditions human eye can detect  $10^{-18}$  J of electromagnetic energy. How many 6000 Å photons does this represent?
- Define the terms: metastable states, optical pumping and population inversion.
- For what kinetic energy will a particle's de Broglie wavelength equal its Compton wavelength?
- If the lifetime of a particular excited state in an atom is  $1.0 \times 10^{-8}$  s, use the uncertainty principle to compute the line width of light emitted by the decay of this excited state.
- A nitrogen nucleus (mass =  $14 \times$  proton mass) emits a photon of energy 6.2 MeV. If the nucleus is initially at rest, what is the recoil energy of the nucleus in eV?
- Write the semi-empirical nuclear binding energy formula for a nucleus of mass number  $A$ , containing  $Z$  protons and  $N$  neutrons explaining each term used in the expression.

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- (g) An electron is confined to a one-dimensional infinite potential well of width  $L = 1.0$  nm. Calculate the energies of the ground state and the first two excited states.
2. (a) Describe Davisson-Germer experiment. Explain how the experiment directly confirms the de Broglie hypothesis of matter wave. 5,2
- (b) Show that the de Broglie wave group associated with a moving particle travels with the same velocity as the particle. 3
- (c) What are the main features of photoelectric effect? Discuss how Classical Physics fails to explain these. 5
3. (a) In a two-slit experiment using electron, a working monitor that can tell through which slit the electron passes destroys the interference pattern on the screen. Explain the observation, using the uncertainty principle. 5,2
- (b) Show, on the basis of uncertainty principle, that electrons cannot reside inside a nucleus. 3
- (c) Use the uncertainty principle to estimate the minimum energy of a particle in a simple harmonic potential  $\frac{1}{2} kx^2$ . 5
4. (a) Discuss the Born probabilistic interpretation of the wave function. Write the conditions required for physical acceptability of wave function. 2,3
- (b) Consider a wave function of the form  

$$\psi(x) = Ae^{-p|x|}$$
 Normalize the wave function. Find the corresponding wave function in momentum space. 4,4
- (c) What are the dimensions of  $\psi(x)$  and  $\psi(p)$ ? 2
5. (a) A particle of energy  $E < V_0$  is incident from left to right on a rectangular potential barrier of height  $V_0$  and width  $a$  as defined below:  

$$V(x) = 0 \quad \text{for } x < 0, \text{ region I}$$

$$= V_0 \quad \text{for } 0 < x < a, \text{ region II}$$

$$= 0 \quad \text{for } x > a, \text{ region III}$$

Write the Schrödinger equations and its physically acceptable solutions in all the three regions. Using these equations show that the reflection coefficient for the particle is given by:

$$R = \frac{\frac{V_0^2}{4E(V_0 - E)} \sinh^2 \beta a}{1 + \frac{V_0^2}{4E(V_0 - E)} \sinh^2 \beta a},$$

where  $\beta = \sqrt{\frac{2m(V_0 - E)}{\hbar^2}}$  8

- (b) A particle of energy  $E$  strikes a potential step  $V_0$ . Taking  $E > V_0$ , distinguish between the classical and quantum behaviour of the particle. Obtain expressions for the reflection coefficient and transmission coefficient. 7
6. (a) Mention the similarities between an atomic nucleus and a liquid drop, on the basis of which the liquid drop model of the nucleus was proposed. Obtain the semi-empirical mass formula of a nucleus. 2,6
- (b) Calculate the binding energy per nucleon for (i) Oxygen-16 (atomic mass = 15.99492 a.m.u.) and (ii) Silicon-29 (atomic mass = 28.97650 a.m.u.). Given that mass of proton = 1.00728 a.m.u. and mass of neutron = 1.00867 a.m.u. 4
- (c) Estimate the mass of  $1 \text{ mm}^3$  of nuclear matter of  $^{227}\text{Th}$  nucleus. 3
7. (a) Radioactive material A (decay constant  $\lambda_a$ ) decays into a material B (decay constant  $\lambda_b$ ) which in turn decays into a stable substance C. Assuming that a sample contains only  $N_{a0}$  nuclei of material A at time  $t = 0$ , determine :
- the number of B nuclei remaining after a time  $t$ ,

- ii. the time at which the number of B nuclei is a maximum, and
- iii. the number of C nuclei remaining after a time  $t$ . 6

(b)  $^{226}\text{Ra}$  has a half-life of 1600 years. What is the activity of a sample of one gram of pure  $^{226}\text{Ra}$ ? What would be the activity of this sample at the end of 400 years? 4,2

(c) How do we explain the emission of Beta-particles from radioactive nuclei even though they are not contained in them? What kind of observations on the energy spectrum of Beta-rays led 'Pauli' to propose the neutrino hypothesis in 1930? 3

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Your Roll No. .... 24/5/18 .....

S. No. of Paper : 6684 HC  
Unique Paper Code : 32221403  
Name of the Paper : Analog Systems and Applications  
Name of the Course : B.Sc. (Hons.) Physics  
Semester : IV  
Duration : 3 hours  
Maximum Marks : 75



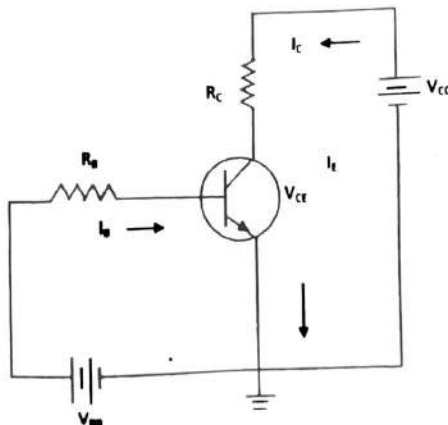
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Attempt five questions in all.  
Question No. 1 is compulsory.

Non-programmable calculators are allowed.

1. Attempt any five of the following:

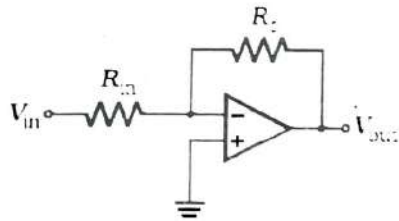
- (a) Define drift and diffusion currents in doped semiconductors.
- (b) Explain with a circuit diagram, how Zener Diode is used in voltage regulation under varying load conditions.
- (c) Draw the IV characteristics of a Solar cell for different intensities of light.
- (d) Calculate the value of  $I_B$ ,  $I_C$  and  $V_{CE}$  for the following circuit, given that  $R_B=470 \text{ k}\Omega$ ;  $R_C = 2.2 \text{ k}\Omega$ ;  $V_{BB}=V_{CC}= 18 \text{ V}$ ;  $\beta=100$ .



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- (e) For a BJT compare the “voltage divider bias circuit” with the “fixed bias circuit” with respect to their stability.
- (f) How does negative feedback, in an Amplifier, improve its stability?
- (g) In the following circuit, open loop gain  $A$  of op-amp is  $2 \times 10^5$  and  $R_{in} = 1 \text{ k}\Omega$ . Find the value of  $R_f$  if the resulting gain with feedback is to be 20 dB.



- (h) Define accuracy and resolution for a D/A converter.

3x5=15

2. (a) Explain the formation of depletion region in a  $p-n$  junction. Derive an expression for the depletion width and barrier potential for  $p-n$  junction.

- (b) A Germanium  $p-n$  step junction has donor density  $N_d = 10^{17} \text{ cm}^{-3}$  on  $n$  side and acceptor density  $N_a = 10^{15} \text{ cm}^{-3}$  on  $p$  side. Calculate the built-in potential at the junction if intrinsic carrier density  $n_i = 10^{13} \text{ cm}^{-3}$ . Assume  $kT/e = 0.026 \text{ V}$ .

10,5

3. (a) Explain with a neat diagram the working of a full wave bridge rectifier. Derive the expression for its ripple factor and the rectification efficiency.

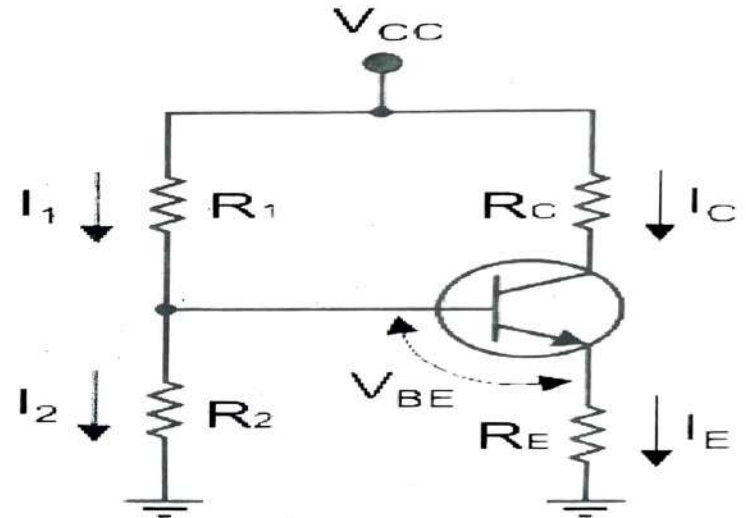
- (b) Give advantages of full wave bridge rectifier over center tap full wave rectifier.

12,3

4. (a) Give the hybrid equivalent circuit of a CE Transistor. Derive the expressions for the current gain, input impedance and output admittance of a CE transistor amplifier using hybrid model.

- (b) In the voltage divider bias circuit given below,  $V_{CC} = 20 \text{ V}$ ,  $R_C = 2 \text{ k}\Omega$ ,  $R_E = 3 \text{ k}\Omega$ ,  $R_1 = 10 \text{ k}\Omega$  and  $R_2 = 6 \text{ k}\Omega$ . Draw the dc load line and determine the Q-point.

10, 5



5. Explain with a neat diagram RC coupled amplifier. Give its equivalent circuits in different frequency ranges. Obtain the expressions for its voltage gain in low and middle frequency regions. Sketch the frequency response curve.

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6. (a) Draw the circuit of a Colpitt Oscillator and explain its working. Derive the expressions for the frequency of oscillations, and the condition for sustained oscillations.



(b) In a phase shift oscillator,  $R = R_L = 10 \text{ k}\Omega$  and  $C = 0.01 \mu\text{F}$ , calculate the time period of oscillation and  $h_{fe}$  of the transistor. 10, 5

7. (a) Draw the circuit of an Op-amp as a Differentiator and explain its operation.

(b) An op-amp integrator has  $R = 1 \text{ M}\Omega$  and  $C = 0.5 \mu\text{F}$ . With input signal  $2 \sin 100\pi t$  determine the output voltage as a function of time assuming that initial voltage across capacitor is zero. Sketch the output in relation to the input.

(c) In the following circuit calculate output voltage if  $V_1 = 5 \text{ V}$  and  $V_2 = 2 \text{ V}$ . 5,5,5

