

2015

PHYSICS

( Major )

Paper : 5.1

Full Marks : 60

Time : 3 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) For the complex number  $z = 3 - 4i$ , find  $z^4$ , given that

$$\tan^{-1} \frac{4}{3} = 53.13^\circ$$

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

(c) Plot the number  $e^{(1 - \pi/6)i}$ .

(d) Find the principal value of  $i^i$ .

2. (a) Solve the equation  $z^4 + 16 = 0$  and plot the values of  $z$ . 2
- (b) Prove :  $\sin^2 z + \cos^2 z = 1$ . 2
3. (a) Check the analyticity of the function  $f(z) = \ln z$  and hence find its derivative. 4
- (b) Find the principal value of  $(2+i)^{1-i}$ . 4

Or

Using Cauchy's integral formula, evaluate the integral

$$\oint \frac{z-1}{z^2+1} dz$$

around the contours—

(i)  $|z-i|=1$

(ii)  $|z|=2$

$2+2=4$

4. (a) State and prove Cauchy's integral theorem. 4
- (b) Define the following with diagram : 3
- (i) Simply connected region
- (ii) Multiply connected region
- (iii) Equivalent contour

Or

- (a) State and prove Taylor's theorem. 4
- (b) Find Taylor series expansion about the origin for  $\sin \pi z$ . 3

5. (a) Define pole and residue.

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(b) If a function  $f(z)$  has an  $m$ th order pole at  $z = a$ , then show that the residue at that singular point is

$$a_{-1} = \frac{1}{(m-1)!} \frac{d^{m-1}}{dz^{m-1}} \left\{ (z-a)^m f(z) \right\}_{z=a}$$

and hence find the residue of

$$f(z) = \frac{e^z}{(z-i)^2}$$

at its pole.

4+2=6

Or

Evaluate the integrals :

3+4=7

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

(ii)  $\int_0^{2\pi} \frac{\sin \theta d\theta}{1+\cos \theta}$

GROUP—B

( Classical Mechanics )

( Marks : 30 )

6. Answer the following questions :

1×4=4

(a) What is areal velocity of a particle?

- (b) The equation of constraint for a particle moving on or out of the surface of a sphere of radius  $r$  is given by

$$x^2 + y^2 + z^2 \geq r^2$$

- What are the two types of constraints that can be associated with the motion of the particle?
- (c) Write down the expression for the Lagrangian of a free particle in cylindrical polar coordinates.
- (d) What is the physical significance of the Hamiltonian of a particle?
7. (a) What are cyclic or ignorable coordinates? If a system undergoes translatory motion along a cyclic generalized coordinate  $q_k$ , will the Lagrangian of the system be affected? 2

- (b) Show that the Poisson bracket of a function with itself is identically zero, i.e.,  $[u, u] = [v, v] = 0$  where  $u$  and  $v$  are any two arbitrary functions. 2

Or

Obtain the Lagrangian equation of motion if the Lagrangian has the form  $L = -(1 - \dot{q}_j^2)^{1/2}$ . Show that the generalized conjugate momentum  $p_j$  is conserved. 4

8. Answer any *three* of the following questions :

4×3=12

- (a) For a particle subjected to a central force, prove that (i) the angular momentum of the particle is a constant of motion, (ii) the particle moves in a fixed plane, and (iii) the areal velocity of the radius vector remains constant.
- (b) The motion of a particle under the influence of a central force is described by  $r = a \sin \theta$ . Find an expression for the force.
- (c) State the d'Alembert's principle. Deduce the Lagrange's equation of motion for a conservative holonomic system using this principle.
- (d) The point of suspension of a pendulum moves in the vertically downward direction with constant acceleration  $a$ . Find the Lagrangian and hence the equation of motion. What will be its period if the downward acceleration  $a$  is the same as that due to gravity?
- (e) Show that the Hamiltonian  $H$  of a system can be written as

$$H = \sum_j p_j \dot{q}_j - L(q_j, \dot{q}_j, t)$$

where  $L(q_j, \dot{q}_j, t)$  is the Lagrangian of the system and  $p_j$  are the generalized momenta,  $q_j$  are the generalized coordinates and  $\dot{q}_j$  are the generalized velocity coordinates.

9. Answer any two questions :

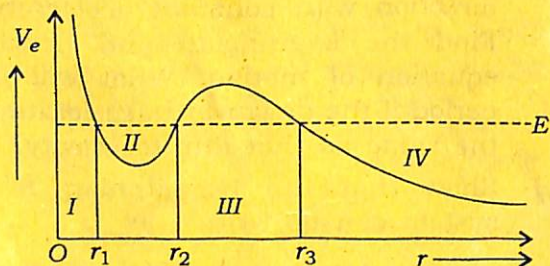
5×2=10

- (a) Assuming attractive inverse square law of force  $F(r) = -k/r^2$ , where  $k > 0$ , show that the speed  $v$  of the particle in the above field is given by

$$v = \sqrt{\frac{k}{m} \left( \frac{2}{r} + \frac{1}{a} \right)}$$

where  $a$  is the semi-major axis of the conical path.

- (b) Referring to the figure given below, consider an arbitrary potential field caused by a central force. Let us suppose that the total energy  $E$  of the particle is represented by the dotted line :



Describe the nature of motion of the particle entering the potential field with energy  $E$  in the regions I, II, III and IV as shown in the figure. What are turning points of motion?

- (c) Using Lagrangian formulation, deduce the equation of motion of a compound pendulum and determine its time period. What is the condition under which the motion of the compound pendulum becomes a simple harmonic motion?
- (d) What are the Hamilton's canonical equations of motion? Using Hamilton's canonical equations, derive the equation of motion of a particle moving in a force field in which the potential is given by  $V = -kx$ , where  $k$  is positive.

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