

R Fundamental definitions and results

R20 $(x_1 + yi)(x_2 + yi) = (x_1x_2 - y_1y_2) + i(x_1y_2 + x_2y_1)$
 $|x + yi| = \sqrt{x^2 + y^2}$, $|x + yi| = \sqrt{x^2 + y^2}$, $d(z_1, z_2) = |z_1 - z_2|$

R1 $\frac{1}{1-z} = 1 + z + z^2 + z^3 + \dots$ for $|z| < 1$

R2 $e^z = 1 + \frac{z}{1!} + \frac{z^2}{2!} + \frac{z^3}{3!} + \dots$ for any z

R3 In the neighbourhood of a pole z_0 of order k
 $f(z) = \frac{a_{-k}}{(z-z_0)^k} + \dots + \frac{a_{-1}}{(z-z_0)} + a_0 + a_1(z-z_0) + \dots$
 and $\text{Res}_{z_0} f = a_{-1} = \lim_{z \rightarrow z_0} ((z-z_0)^k f(z))^{(k-1)}$

R4 Complex integral of $f: D \rightarrow \mathbb{C}$ along $\gamma: [a, b] \rightarrow D$ is
 $\int_{\gamma} f(z) dz = \int_a^b f(\gamma(t)) \gamma'(t) dt$

R3 Theorem of Residues. For an open set $D \subset \mathbb{C}$:

$f: D \rightarrow \mathbb{C}$ holomorphic function
 S set of isolated singular points
 γ path homotopic to zero in $D \setminus S$

$$\int_{\gamma} f(z) dz = 2\pi i \sum_{z \in S} n(z, \gamma) \text{Res}_z f$$

R4 Lemma 1. For $\gamma_r: [0, \beta] \rightarrow \mathbb{C}$, $\gamma_r(t) = re^{it}$
 $\lim_{r \rightarrow \infty} z f(z) = 0 \Rightarrow \lim_{r \rightarrow \infty} \int_{\gamma_r} f(z) dz = 0$

R5 Lemma 2 (Jordan). For $\gamma_r: [0, \pi] \rightarrow \mathbb{C}$, $\gamma_r(t) = re^{it}$
 $\lim_{r \rightarrow \infty} f(z) = 0 \Rightarrow \lim_{r \rightarrow \infty} \int_{\gamma_r} f(z) e^{iz} dz = 0$

A Problems

1 $(1-2i)^2 = ?$, $\frac{1-i}{1+i} = ?$, $e^{-2i} = ?$, $d(1+i, 2-i) = ?$,
 $(z \sin z)' = ?$, $(e^z)' = ?$, $\lim_{z \rightarrow \infty} \left(\frac{z}{z^2} + \frac{1}{z} \right) = ?$.

2 Expand in a power series of z the functions
 $f_1(z) = e^{z^2}$, $f_2(z) = ze^{z^2}$, $f_3(z) = \frac{1}{1-z^2}$

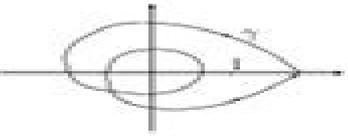
Solution.
 $f_1(z) = 1 + \frac{z^2}{1!} + \frac{z^4}{2!} + \frac{z^6}{3!} + \dots$ for any z .
 $f_2(z) = z \left(1 + \frac{z^2}{1!} + \frac{z^4}{2!} + \frac{z^6}{3!} + \dots \right) = \dots + \frac{z^3}{1!} + \frac{z^5}{2!} + z + \dots$ for $|z| > 0$.
 $f_3(z) = \frac{1}{1-z^2} \left(1 + z + z^2 + z^3 + \dots \right) = \frac{1}{1-z} + \frac{z}{1-z^2} + \dots$ for $0 < |z| < 1$.

3 Compute the residues of $f(z) = \frac{1}{z^3(z-1)^2}$
Hint. 0 is a pole of order 3 and ± 1 are poles of order 2.

B Problems

1 Prove that $f: \mathbb{C} \rightarrow \mathbb{C}$, $f(z) = 1+z$ is not \mathbb{C} -differentiable.
Hint. Use the Cauchy-Riemann theorem.

2 For $\gamma: [0, \pi] \rightarrow \mathbb{C}$, $\gamma(t) = e^{it}$, compute $\int_{\gamma} (z+i) dz$.
Hint. Use the definition of the complex line integral.



3 Compute the integral $\int_{\gamma} \frac{1}{z^2(z-1)} dz$ where γ is the path from the figure above.

Solution. By using the theorem of residues, we get
 $\int_{\gamma} \frac{1}{z^2(z-1)} dz = 2\pi i (2 \text{Res}_0 f + \text{Res}_1 f) = 2\pi i$.

4 Compute the residue of $f(z) = ze^{z^2}$ at the singular point $z_0 = 0$.
Solution. $f(z) = \dots + \frac{z}{1!} + \frac{z^3}{3!} + \dots + 1 + z$ for any $z \Rightarrow \text{Res}_0 f = \frac{1}{2}$.

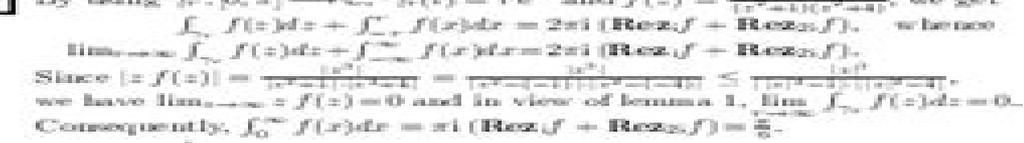
C Problems

1 Compute the residues of $f(z) = z^2 e^{-z^2}$ at the singular point $z_0 = 1$.
Hint. $f(z) = ((z-1)^2 + 2(z-1) + 1) \left(1 + \frac{1}{2} \frac{z-1}{1!} + \frac{1}{2!} \frac{(z-1)^2}{2!} + \frac{1}{3!} \frac{(z-1)^3}{3!} + \dots \right)$.

2 Compute the integrals $I_1 = \int_0^{2\pi} \frac{1}{2+\cos t} dt$ and $I_2 = \int_0^{2\pi} \frac{1}{2-\cos t} dt$
Solution. By using the path $\gamma: [0, 2\pi] \rightarrow \mathbb{C}$, $\gamma(t) = e^{it}$, we get
 $I_1 = \int_0^{2\pi} \frac{1}{2+\cos t} dt = \int_0^{2\pi} \frac{1}{2+\frac{z+z^{-1}}{2}} dz = \int_{\gamma} \frac{2dz}{4+z+z^{-1}} = \int_{\gamma} \frac{2z dz}{4z^2+z+1}$
 $= -i \int_{\gamma} \frac{1}{\frac{1}{2} + \frac{z^2}{4} + \frac{z}{2}} dz = -i \int_{\gamma} \frac{2}{z^2+z+2} dz = 2\pi \text{Res}_{-2+\sqrt{3}} \frac{2}{z^2+z+2} = \frac{2\pi}{\sqrt{3}}$

3 Compute the integrals $\int_0^{\infty} \frac{1}{1+x^2} dx$ and $\int_0^{\infty} \frac{x}{1+x^2} dx$
Solution. The integral is convergent: at infinity $\frac{1}{1+x^2} \sim \frac{1}{x^2}$.
 By using $\gamma_r: [0, \pi] \rightarrow \mathbb{C}$, $\gamma_r(t) = re^{it}$ and $f(z) = \frac{1}{1+z^2}$, we get
 $\int_{\gamma_r} f(z) dz = \int_0^{\pi} f(x) dx + \int_{\gamma_r} f(z) dz = 2\pi i (\text{Res}_i f + \text{Res}_{-i} f)$, whence
 $\lim_{r \rightarrow \infty} \int_{\gamma_r} f(z) dz + \int_{-\infty}^{\infty} f(x) dx = 2\pi i (\text{Res}_i f + \text{Res}_{-i} f)$.

Since $|z f(z)| = \frac{|z|}{|1+z^2|} = \frac{|z|}{|z^2-1|+1} \leq \frac{|z|}{|z|^2-|z|+1} \leq \frac{|z|}{|z|^2-|z|}$, we have $\lim_{r \rightarrow \infty} z f(z) = 0$ and in view of lemma 1, $\lim_{r \rightarrow \infty} \int_{\gamma_r} f(z) dz = 0$.
 Consequently, $\int_0^{\infty} f(x) dx = \pi i (\text{Res}_i f + \text{Res}_{-i} f) = \frac{\pi}{2}$.



4 Prove that $\int_0^{\infty} \frac{\sin x}{x} dx = \frac{\pi}{2}$ (Poisson's integral).

Solution. Let $0 < r < R$ and $\gamma_R, \gamma_r: [0, \pi] \rightarrow \mathbb{C}$, $\gamma_R(t) = Re^{it}$, $\gamma_r(t) = re^{it}$.
 From the residue theorem (right hand side of fig.) it follows the relation
 $\int_{\gamma_R} \frac{e^{iz}}{z} dz + \int_{-\gamma_r} \frac{e^{iz}}{z} dz + \int_{\gamma_r} \frac{e^{iz}}{z} dz + \int_{-\gamma_R} \frac{e^{iz}}{z} dz = 0$, that is
 $\int_{\gamma_R} \frac{e^{iz}}{z} dz + \int_{\gamma_r} \frac{e^{iz}}{z} dz + \int_r^R \frac{e^{ix}-e^{-ix}}{x} dx + 2i \int_r^R \frac{\sin x}{x} dx = 0$,
 $\int_{\gamma_R} \frac{e^{iz}}{z} dz + \int_{\gamma_r} \frac{e^{iz}}{z} dz + \int_r^R \frac{e^{ix}-e^{-ix}}{x} dx + 2i \int_r^R \frac{\sin x}{x} dx = 0$.

If g is an antiderivative of $f(z) = \frac{e^{iz}}{z}$, by using $\int_{\gamma_r} \frac{1}{z} dz = -\pi i$, we get
 $\int_{\gamma_R} \frac{e^{iz}}{z} dz - \pi i + (g(r) - g(-r)) + 2i \int_r^R \frac{\sin x}{x} dx = 0$.
 But, in view of Jordan's lemma $\lim_{R \rightarrow \infty} \int_{\gamma_R} \frac{e^{iz}}{z} dz = 0$,
 and for $R \rightarrow \infty$ and $r \rightarrow 0$ we get $2i \int_0^{\infty} \frac{\sin x}{x} dx = \pi i$.

5 Find the holomorphic function $f: \mathbb{C} \rightarrow \mathbb{C}$ with $\frac{\partial f}{\partial x}(x+yi) = 2xy - 2x$, $f(i) = 0$.

6 For $z_0 \neq 0$, expand $f: \mathbb{C}^* \rightarrow \mathbb{C}$, $f(z) = \frac{1}{z}$ in a power series of $(z-z_0)$.
Solution. We have
 $f(z) = \frac{1}{z_0+z-z_0} = \frac{1}{z_0} \frac{1}{1-\frac{z-z_0}{z_0}} = \frac{1}{z_0} \left(1 - \frac{z-z_0}{z_0} + \frac{(z-z_0)^2}{z_0^2} - \dots \right)$,
 for $|z-z_0| < |z_0|$.
 $f(z) = \frac{1}{z_0+z-z_0} = \frac{1}{z_0} \frac{1}{1-\frac{z-z_0}{z_0}} = \frac{1}{z_0} \left(1 - \frac{z-z_0}{z_0} + \frac{(z-z_0)^2}{z_0^2} - \dots \right)$,
 for $|z-z_0| > |z_0|$.

7 Expand in a power series of $(z-i)$ the functions:
 $f_1(z) = \frac{1}{z}$, $f_2(z) = \frac{1}{z^2}$, $f_3(z) = \frac{1}{z} + \frac{1}{z^2}$.

Complex Analysis Problems And Solutions

**Dennis G. Zill, Patrick
Shanahan, Patrick D. Shanahan**



Complex Analysis Problems And Solutions :

Problems and Solutions for Complex Analysis Rami Shakarchi, 2012-12-06 This book contains all the exercises and solutions of Serge Lang's *Complex Analysis* Chapters I through VIII of Lang's book contain the material of an introductory course at the undergraduate level and the reader will find exercises in all of the following topics power series Cauchy's theorem Laurent series singularities and meromorphic functions the calculus of residues conformal mappings and harmonic functions Chapters IX through XVI which are suitable for a more advanced course at the graduate level offer exercises in the following subjects Schwarz reflection analytic continuation Jensen's formula the Phragmén-Lindelöf theorem entire functions Weierstrass products and meromorphic functions the Gamma function and the Zeta function This solutions manual offers a large number of worked out exercises of varying difficulty I thank Serge Lang for teaching me complex analysis with so much enthusiasm and passion and for giving me the opportunity to work on this answer book Without his patience and help this project would be far from complete I thank my brother Karim for always being an infinite source of inspiration and wisdom Finally I want to thank Mark McKee for his help on some problems and Jennifer Baltzell for the many years of support friendship and complicity Rami Shakarchi Princeton New Jersey 1999 Contents Preface vii I Complex Numbers and Functions 1 1 1 Definition 1 1 2 Polar Form 3 1 3 Complex Valued Functions 8 1 4 Limits and Compact Sets 9 1 6 The Cauchy-Riemann Equations

Complex Analysis with Applications Nakhlé H. Asmar, Loukas Grafakos, 2018-10-12 This textbook is intended for a one semester course in complex analysis for upper level undergraduates in mathematics Applications primary motivations for this text are presented hand in hand with theory enabling this text to serve well in courses for students in engineering or applied sciences The overall aim in designing this text is to accommodate students of different mathematical backgrounds and to achieve a balance between presentations of rigorous mathematical proofs and applications The text is adapted to enable maximum flexibility to instructors and to students who may also choose to progress through the material outside of coursework Detailed examples may be covered in one course giving the instructor the option to choose those that are best suited for discussion Examples showcase a variety of problems with completely worked out solutions assisting students in working through the exercises The numerous exercises vary in difficulty from simple applications of formulas to more advanced project type problems Detailed hints accompany the more challenging problems Multi part exercises may be assigned to individual students to groups as projects or serve as further illustrations for the instructor Widely used graphics clarify both concrete and abstract concepts helping students visualize the proofs of many results Freely accessible solutions to every other odd exercise are posted to the book's Springer website Additional solutions for instructors use may be obtained by contacting the authors directly

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practicing engineers and researchers in the physical sciences for considerable attention is given to those problems which illustrate the application of the theory of functions of a complex variable to problems dealing with the mechanics of continuous media and electrical engineering The problems themselves range in difficulty from elementary to those encountered only in more advanced treatments The first four chapters involve complex numbers and functions of a complex variable conformal mappings connected with elementary functions supplementary geometrical questions and generalized analytic functions and integrals and power series Chapters V through VIII cover the Laurent series singularities of single valued functions and integral functions various series of functions parametric integrals and infinite products residues and their applications integrals of the Cauchy type and integral functions of Poisson and Schwarz The final three chapters discuss analytic continuation singularities of many valued character and Riemann Surfaces conformal mappings and applications to mechanic and physics Answers and solutions are grouped at the end of the text

Complex Analysis Dennis G. Zill, Patrick D. Shanahan, 2013-09-20 Designed for the undergraduate student with a calculus background but no prior experience with complex analysis this text discusses the theory of the most relevant mathematical topics in a student friendly manner With a clear and straightforward writing style concepts are introduced through numerous examples illustrations and applications Each section of the text contains an extensive exercise set containing a range of computational conceptual and geometric problems In the text and exercises students are guided and supported through numerous proofs providing them with a higher level of mathematical insight and maturity Each chapter contains a separate section devoted exclusively to the applications of complex analysis to science and engineering providing students with the opportunity to develop a practical and clear understanding of complex analysis The Mathematica syntax from the second edition has been updated to coincide with version 8 of the software

Problems and Solutions in Real Analysis Masayoshi Hata, 2007 This unique book provides a collection of more than 200 mathematical problems and their detailed solutions which contain very useful tips and skills in real analysis Each chapter has an introduction in which some fundamental definitions and propositions are prepared This also contains many brief historical comments on some significant mathematical results in real analysis together with useful references *Problems and Solutions in Real Analysis* may be used as advanced exercises by undergraduate students during or after courses in calculus and linear algebra It is also useful for graduate students who are interested in analytic number theory Readers will also be able to completely grasp a simple and elementary proof of the prime number theorem through several exercises The book is also suitable for non experts who wish to understand mathematical analysis

A Complex Analysis Problem Book Daniel Alpay, 2016-10-26 This second edition presents a collection of exercises on the theory of analytic functions including completed and detailed solutions It introduces students to various applications and aspects of the theory of analytic functions not always touched on in a first course while also addressing topics of interest to electrical engineering students e g the realization of rational functions and its connections to the theory of linear systems and state

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Havin,Nikolai K. Nikolski,2006-12-08 The 2 volume book is an updated reorganized and considerably enlarged version of the previous edition of the Research Problem Book in Analysis LNM 1043 a collection familiar to many analysts that has sparked off much research This new edition created in a joint effort by a large team of analysts is like its predecessor a collection of unsolved problems of modern analysis designed as informally written mini articles each containing not only a statement of a problem but also historical and methodological comments motivation conjectures and discussion of possible connections of plausible approaches as well as a list of references There are now 342 of these mini articles almost twice as many as in the previous edition despite the fact that a good deal of them have been solved **Problems in Real and Complex Analysis**

Bernard R. Gelbaum,1992-01-01 **A First Course in Complex Analysis with Applications** Dennis G. Zill,Patrick Shanahan,Patrick D. Shanahan,2006-07 A First Course In Complex Analysis With Applications Limits Theoretical Coverage To Only What Is Necessary And Conveys It In A Student Friendly Style Its Aim Is To Introduce The Basic Principles And Applications Of Complex Analysis To Undergraduates Who Have No Prior Knowledge Of This Subject Contents Of The Book Include The Complex Number System Complex Functions And Sequences As Well As Real Integrals In Addition To Other Concepts Of Calculus And The Functions Of A Complex Variable This Text Is Written For Junior Level Undergraduate Students Who Are Majoring In Math Physics Computer Science And Electrical Engineering **Complex Analysis through**

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book can be used either as a classroom text or for independent study Written at a level accessible to advanced undergraduates and beginning graduate students the book is suitable for readers acquainted with advanced calculus or introductory real analysis The treatment goes beyond the standard material of power series Cauchy s theorem residues conformal mapping and harmonic functions by including accessible discussions of intriguing topics that are uncommon in a book at this level The flexibility afforded by the supplementary topics and applications makes the book adaptable either to a short one term course or to a comprehensive full year course Detailed solutions of the exercises both serve as models for students and facilitate independent study Supplementary exercises not solved in the book provide an additional teaching tool

Complex Analysis and Differential Equations Luis Barreira,Claudia Valls,2012-04-23 This text provides an accessible self contained and rigorous introduction to complex analysis and differential equations Topics covered include holomorphic functions Fourier series ordinary and partial differential equations The text is divided into two parts part one focuses on complex analysis and part two on differential equations Each part can be read independently so in essence this text offers two books in one In the second part of the book some emphasis is given to the application of complex analysis to differential equations Half of the book consists of approximately 200 worked out problems carefully prepared for each part of theory plus 200 exercises of variable levels of difficulty Tailored to any course giving the first introduction to complex analysis or differential equations this text assumes only a basic knowledge of linear algebra and differential and integral calculus Moreover the large number of examples worked out problems and exercises makes this the ideal book for independent study

University of Colorado Catalogue University of Colorado,1929 *Bulletin* University of Colorado Boulder,1928

Riemann-Hilbert Problems, Their Numerical Solution, and the Computation of Nonlinear Special Functions Thomas Trogdon,Sheehan Olver,2015-12-22 Riemann Hilbert problems are fundamental objects of study within complex analysis Many problems in differential equations and integrable systems probability and random matrix theory and asymptotic analysis can be solved by reformulation as a Riemann Hilbert problem This book the most comprehensive one to date on the applied and computational theory of Riemann Hilbert problems includes an introduction to computational complex analysis an introduction to the applied theory of Riemann Hilbert problems from an analytical and numerical perspective and a

discussion of applications to integrable systems differential equations and special function theory It also includes six fundamental examples and five more sophisticated examples of the analytical and numerical Riemann Hilbert method each of mathematical or physical significance or both *College of Engineering* University of Michigan. College of Engineering, 1974 [A Course in Mathematical Analysis: pt.2. Differential equations. \[c1917](#) Edouard Goursat, 1916

Complex Analysis M. D. PETALE, Purpose of this Book The purpose of this book is to supply lots of examples with details solution that helps the students to understand each example step wise easily and get rid of the college assignments phobia It is sincerely hoped that this book will help and better equipped the higher secondary students to prepare and face the examinations with better confidence I have endeavored to present the book in a lucid manner which will be easier to understand by all the engineering students About the Book According to many streams in engineering course there are different chapters in Engineering Mathematics of the same year according to the streams Hence students faced problem about to buy Engineering Mathematics special book that covered all chapters in a single book That s reason student needs to buy many books to cover all chapters according to the prescribed syllabus Hence need to spend more money for a single subject to cover complete syllabus So here good news for you your problem solved I made here special books according to chapter wise which helps to buy books according to chapters and no need to pay extra money for unneeded chapters that not mentioned in your syllabus PREFACE It gives me great pleasure to present to you this book on A Textbook on Complex Analysis of Engineering Mathematics presented specially for you Many books have been written on Engineering Mathematics by different authors and teachers but majority of the students find it difficult to fully understand the examples in these books Also the Teachers have faced many problems due to paucity of time and classroom workload Sometimes the college teacher is not able to help their own student in solving many difficult questions in the class even though they wish to do so Keeping in mind the need of the students the author was inspired to write a suitable text book providing solutions to various examples of Complex Analysis of Engineering Mathematics It is hoped that this book will meet more than an adequately the needs of the students they are meant for I have tried our level best to make this book error free

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