

**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  $\text{Res}_{z_0} f = a_{-1} = \frac{1}{(k-1)!} \lim_{z \rightarrow z_0} ((z-z_0)^k f(z))^{(k-1)}$

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

**R5 Theorem of Residues.** For an open set  $D \subset \mathbb{C}$ :

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

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

**R6 Lemma 1.** For  $\gamma_r: [0, \beta] \rightarrow \mathbb{C}$ ,  $\gamma_r(t) = re^{it}$   
 $\lim_{r \rightarrow \infty} z f(z) = 0 \Rightarrow \lim_{r \rightarrow \infty} \int_{\gamma_r} f(z) dz = 0$

**R7 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**  $(1-2i)^2 = ?$ ,  $\frac{1}{1+i} = ?$ ,  $e^{-2i} = ?$ ,  $d(1+i, 2-i) = ?$ ,  
 $(z \sin z)' = ?$ ,  $(e^z)' = ?$ ,  $\lim_{z \rightarrow \infty} \left( \frac{z}{z^2} + \frac{1}{z} \right) = ?$ .

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

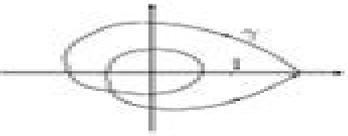
**Solution.**  
 $f_1(z) = 1 + \frac{z^2}{1!} + \frac{z^4}{2!} + \frac{z^6}{3!} + \dots$  for any  $z$ .  
 $f_2(z) = z \left( 1 + \frac{z^2}{1!} + \frac{z^4}{2!} + \frac{z^6}{3!} + \dots \right) = \dots + \frac{z^3}{1!} + \frac{z^5}{2!} + z + \dots$  for  $|z| > 0$ .  
 $f_3(z) = \frac{1}{1-z^2} \left(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

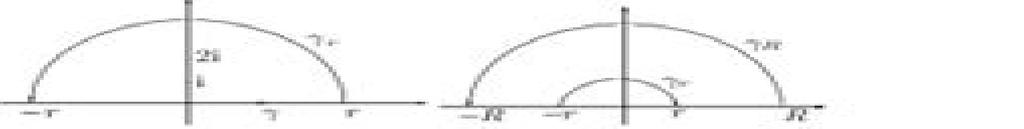
**2** Compute the integrals  $I_1 = \int_0^{2\pi} \frac{1}{2+\cos t} dt$  and  $I_2 = \int_0^{2\pi} \frac{1}{2-\cos t} dt$   
**Solution.** By using the path  $\gamma: [0, 2\pi] \rightarrow \mathbb{C}$ ,  $\gamma(t) = e^{it}$ , we get  
 $I_1 = \int_0^{2\pi} \frac{1}{2+\cos t} dt = \int_0^{2\pi} \frac{1}{2+\frac{z+z^{-1}}{2}}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

**3** Compute the integrals  $\int_0^{\infty} \frac{1}{1+x^2} dx$  and  $\int_0^{\infty} \frac{1}{1+x^2+2x} dx$   
**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  
 $\int_{\gamma_r} f(z) dz = \int_0^{\pi} f(x) dx = 2\pi i (\text{Res}_i f + \text{Res}_{-i} f)$ , 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  $|z f(z)| = \frac{|z|}{|1+z^2|} = \frac{|z|}{|z^2-1|} \leq \frac{|z|}{|z|^2-1}$ , 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  
 $\int_{\gamma_R} \frac{e^{iz}}{z} dz + \int_{\gamma_r} \frac{e^{iz}}{z} dz + \int_{\gamma} \frac{e^{iz}}{z} dz + \int_{\gamma} \frac{e^{iz}}{z} dz = 0$ , that is  
 $\int_{\gamma_R} \frac{e^{iz}}{z} dz + \int_{\gamma_r} \frac{e^{iz}}{z} dz + \int_r^R \frac{e^{ix}}{x} dx + 2i \int_0^{\pi} \frac{\sin x}{x} dx = 0$ .  
 $\int_{\gamma_R} \frac{e^{iz}}{z} dz - \pi i + (g(R) - g(-R)) + 2i \int_0^{\pi} \frac{\sin x}{x} dx = 0$ .  
 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 Pdf

**Prem K. Kythe**



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**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

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*A Collection of Problems on Complex Analysis* Lev Izrailevich Volkovskii, G. L. Lunts, Isaak Genrikhovich Aramanovich, 1991 This comprehensive collection contains over 1 500 problems on the theory of functions of the complex variable and covers nearly every branch of classical function theory It will be of special interest to 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

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*Proceedings of the 12th Workshop on Electronics for LHC and Future Experiments, Valencia, Spain, 25-29 September 2006*, 2007 **Reviews in Complex Analysis, 1980-1986**, 1989 Engineering Problem-Solving 101: Time-Tested and

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*Responsibility to the Green Growth of Business and Economy* Elena G. Popkova, 2025-04-28 The book is devoted to the scientific study of the international experience and prospects of the sustainable development of business in the economy of the digital technological mode It outlines the imperatives of the sustainable development of business in the economy of the digital technological mode The role of environmental innovations in the sustainable development of business in the context of the spheres of the economy of the digital technological mode The international experience of the international development of business in the economy of the digital technological mode is considered and discussed The practical and case experience of the sustainable development of business in the economy of the digital technological mode in Central Asia is given The prospects are outlined and recommendations are offered for the sustainable development of business in the economy of the digital technological mode **Student Study Guide to Accompany A First Course in Complex Analysis with**

**Applications** Patrick D. Shanahan, 2009-09-29 Twelfth International Conference on VLSI Design VLSI Society of India, IEEE Circuits and Systems Society, 1999 The proceedings of the January 1999 conference consist of 103 papers 11 talks and six tutorials The papers are grouped under the headings of TCAD to ECAD low power testing co design and synthesis analog design multi valued logic verification digital signal processor DSP logic synthesis 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

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