

# **Mathematical Expression Detection and Segmentation in Document Images**

**Jacob R. Bruce**

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science  
In  
Computer Engineering

A. Lynn Abbott, Committee Chair  
Jianhua J. Xuan, Co-Chair  
Michael S. Hsiao

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Keywords: document layout analysis, optical character recognition, mathematical expression detection and segmentation, document image, type-specific layout analysis

**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## **Virginia Tech ETD Fair Use Analysis Results**

***This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.***

Name: Jake Bruce

Description of item under review for fair use: "Statistical Machine" P. W. Handel, "Statistical Machine," United States Patent Office. 1,915,993, Jun. 27, 1933.

Report generated on: 02-25-2014 at : 16:22:06

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

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***This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.***

Name: Jake Bruce

Description of item under review for fair use: Contributor: Bob Stein (uploaded to <http://archive.org>), "New York Times August September 1901 Collection," Internet:  
[http://archive.org/download/NewYorkTimesAugSept1901Collection/New\\_York\\_Times\\_August\\_September\\_1901\\_Part\\_7\\_text.pdf](http://archive.org/download/NewYorkTimesAugSept1901Collection/New_York_Times_August_September_1901_Part_7_text.pdf),  
Date Accessed: 2013.

Report generated on: 02-25-2014 at : 16:25:45

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

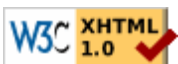
#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





**Draft 09/01/2009**

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## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Jacob R. Bruce

Description of item under review for fair use: R. Griffin, Statistics. London: Macmillon and Co., 1913, pp. 121-122

Report generated on: 02-25-2014 at : 16:34:37

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

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Name: Jacob R. Bruce

Description of item under review for fair use: M. Martin, "Reading Machine Speaks Out Loud," Popular Science, vol. 154, no. 2, Feb 1949, pp. 125-127

Report generated on: 02-25-2014 at : 16:35:47

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





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Name: Jacob R. Bruce

Description of item under review for fair use: The IBM 1401 Demo Lab and Restoration Project Computer History Museum, "IBM 1401 Archive Pics," Internet: [http://ibm-1401.info/IBM1401\\_ArchivePics.html](http://ibm-1401.info/IBM1401_ArchivePics.html), Date Accessed: 2014.

Report generated on: 02-25-2014 at : 16:38:42

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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***This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.***

Name: Jacob R. Bruce

Description of item under review for fair use: J. J. Hull, and S. L. Taylor. "Document Image Skew Detection: Survey and Annotated Bibliography," World Scientific, 1998, pp. 40-64.

Report generated on: 02-25-2014 at : 16:40:54

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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***This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.***

Name: Jacob R. Bruce

Description of item under review for fair use: R. Smith, "Apparatus and Method for Use in Image Processing," United States Patent Office. 5,583,949, Dec 10, 1996.

Report generated on: 02-25-2014 at : 16:42:18

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Jacob R. Bruce

Description of item under review for fair use: R. Smith. "An Overview of the Tesseract OCR Engine," Proc. Int. Conf. Document Analysis Recognition, 2007, pp. 629-633.

Report generated on: 02-25-2014 at : 16:45:16

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





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Name: Jacob R. Bruce

Description of item under review for fair use: R. Smith. "Tesseract OCR Engine: What It Is, Where It Came From, Where It Is Going," OSCON, 2007.

Report generated on: 02-25-2014 at : 16:47:05

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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## Virginia Tech ETD Fair Use Analysis Results

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Name: Jacob R. Bruce

Description of item under review for fair use: S. Mori, C. Y. Suen, and K. Yamamoto, "Historical Review of OCR Research and Development," Proceedings of the IEEE, vol. 80, no. 7, Jul 1992, pp. 1029-1058. Used under fair use, 2014.

Report generated on: 02-25-2014 at : 16:49:57

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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## Virginia Tech ETD Fair Use Analysis Results

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Name: Jacob R. Bruce

Description of item under review for fair use: Aforge.NET, "Blobs Processing," Internet: [http://www.aforgenet.com/framework/features/blobs\\_processing.html](http://www.aforgenet.com/framework/features/blobs_processing.html), Date Accessed: 2013.

Report generated on: 02-25-2014 at : 16:56:56

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *against fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Jacob R. Bruce

Description of item under review for fair use: A. M. Namboodiri, and A. Jain. "Document Structure and Layout Analysis," Advances in Pattern Recognition, Springer-Verlag, London 2007.

Report generated on: 02-25-2014 at : 17:01:59

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





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Name: Jacob R. Bruce

Description of item under review for fair use: R. Miller, "Ink-Jet Basics," Internet: [http://www.thetonesystem.com/inkjet\\_basics.html](http://www.thetonesystem.com/inkjet_basics.html), Date Accessed: 2013.

Report generated on: 02-25-2014 at : 17:06:43

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

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## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Jacob R. Bruce

Description of item under review for fair use: A. Gourdol, "CSS3 Regions: Rich Page Layout With HTML And CSS3," Internet: <http://www.adobe.com/devnet/html5/articles/css3-regions.html>, Date Accessed: 2013.

Report generated on: 02-25-2014 at : 17:16:11

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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***This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.***

Name: Jacob R. Bruce

Description of item under review for fair use: G. Nagy, S. Seth, and M. Viswanathan, "A Prototype Document Image Analysis System for Technical Journals," Computer, vol. 25, no. 1, Jan 1992, pp. 10-22

Report generated on: 02-25-2014 at : 17:17:14

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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Name: Jacob R. Bruce

Description of item under review for fair use: J. P. Bixler. "Tracking Text in Mixed-Mode Document," Proc. ACM Conference on Document Processing System, 1998, pp. 177-185.

Report generated on: 02-25-2014 at : 17:19:22

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





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Name: Jacob R. Bruce

Description of item under review for fair use: L. O'Gorman, "The Document Spectrum for Page Layout Analysis," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 15, no. 11, Nov 1993, pp. 162-173.

Report generated on: 02-25-2014 at : 17:20:31

### **Based on the information you provided:**

#### **Factor 1**

Your consideration of the purpose and character of your use of the copyright work weighs: ***in favor of fair use***

#### **Factor 2**

Your consideration of the nature of the copyrighted work you used weighs: ***in favor of fair use***

#### **Factor 3**

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: ***in favor of fair use***

#### **Factor 4**

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: ***in favor of fair use***

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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Name: Jacob R. Bruce

Description of item under review for fair use: Wikipedia, "Voronoi Diagram," Internet: [http://en.wikipedia.org/wiki/Voronoi\\_diagram](http://en.wikipedia.org/wiki/Voronoi_diagram), Date Accessed: 2013.

Report generated on: 02-25-2014 at : 17:23:56

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

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Name: Jacob R. Bruce

Description of item under review for fair use: Kise et al. K. Kise, A. Sata, and M. Iwata, "Segmentation of Page Images Using the Area Voronoi Diagram," Computer Vision and Image Understanding, vol. 70, no. 3, Jun 1998, pp. 370-382.

Report generated on: 02-25-2014 at : 17:26:55

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



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Name: Jacob R. Bruce

Description of item under review for fair use: F. Wahl, K. Wong, and R. Casey, "Block Segmentation and Text Extraction in Mixed Text/Image Documents," Graphical Models and Image Processing, vol. 20, no. 1, Jan 1982, pp. 375-390.

Report generated on: 02-25-2014 at : 17:29:08

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

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Description of item under review for fair use: D. S. Bloomberg. "Multiresolution Morphological Approach to Document Image Analysis," 1st International Conference of Document Analysis and Recognition, 1991, pp. 963-971.

Report generated on: 02-25-2014 at : 17:30:50

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

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Name: Jacob R. Bruce

Description of item under review for fair use: F. Shafait. "Geometric Layout Analysis of Scanned Documents," PhD thesis, University of Kaiserslautern, 2008.

Report generated on: 02-25-2014 at : 17:32:48

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Jacob R. Bruce

Description of item under review for fair use: A. Kacem, A. Belaid, B. M. Ahmed, "Automatic Extraction of Printed Mathematical Formulas using Fuzzy Logic and Propagation of Context," International Journal of Document Analysis and Recognition, vol. 4, no. 2, December 2001, pp. 97-108.

Report generated on: 02-25-2014 at : 17:36:01

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *in favor of fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***



**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Jacob R. Bruce

Description of item under review for fair use: D. Sloughter, Difference Equations to Differential Equations: An Introduction to Calculus. Furman University, Greenville, SC: Creative Commons, 2000.

Report generated on: 03-09-2014 at : 18:21:55

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *against fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***





**Draft 09/01/2009**

(Questions? Concerns? Contact Gail McMillan, Director of the Digital Library and Archives at Virginia Tech's University Libraries: [gailmac@vt.edu](mailto:gailmac@vt.edu))

(Please ensure that Javascript is enabled on your browser before using this tool.)

## Virginia Tech ETD Fair Use Analysis Results

*This is not a replacement for professional legal advice but an effort to assist you in making a sound decision.*

Name: Jacob R. Bruce

Description of item under review for fair use: A. S Kompaneyets, Theoretical Physics. Osmania University: Foreign Languages Publishing House, 1961.

Report generated on: 03-09-2014 at : 18:25:31

### Based on the information you provided:

#### Factor 1

Your consideration of the purpose and character of your use of the copyright work weighs: *in favor of fair use*

#### Factor 2

Your consideration of the nature of the copyrighted work you used weighs: *against fair use*

#### Factor 3

Your consideration of the amount and substantiality of your use of the copyrighted work weighs: *in favor of fair use*

#### Factor 4

Your consideration of the effect or potential effect on the market after your use of the copyrighted work weighs: *in favor of fair use*

**Based on the information you provided, your use of the copyrighted work weighs: *in favor of fair use***

