2015-2016 LONG SIGNATURE SHEET

RECEIVED 11-02-15

UNC CHARLOTTE

Proposal Number: MATH 10-09-15

Proposal Title: Establishment of New Course MATH 7180/8180

Originating Department: Mathematics and Statistics

TYPE OF PROPOSAL: UNDERGRADUATE______ GRADUATE__X__ UNDERGRADUATE & GRADUATE____
(Separate proposals sent to UCCC and Grad. Council)

DATE RECEIVED	DATE CONSIDERED	DATE FORWARDED	ACTION	SIGNATURES
10/09/2015	10/09/2015	10/09/2015	Approved	DEPARTMENT CHAIR Yuanan Diao [signature]
			Approved	COLLEGE CURRICULUM COMMITTEE CHAIR Janet E. Levy [print name here:] Janet E Levy
			Approved	COLLEGE FACULTY CHAIR (if applicable) Elizabeth Stearns [print name here:] Elizabeth Stearns
			Approved	COLLEGE DEAN [signature] [print name here:] Shawn Long
			Approved	GENERAL EDUCATION (if applicable; for General Education courses) [print name here:]
			Approved	HONORS COLLEGE (if applicable; for Honors courses & programs) [print name here:]
			Approved	UNDERGRADUATE COURSE & CURRICULUM COMMITTEE CHAIR (for undergraduate content)
12/7/15	1/5/16	2/2/16	Approved	GRADUATE COUNCIL CHAIR (for graduate content) [signature] Denis Livesay
				FACULTY GOVERNANCE ASSISTANT (Faculty Council approval on Consent Calendar)
				FACULTY EXECUTIVE COMMITTEE (if decision is appealed)

UNC CHARLOTTE

LONG FORM
COURSE AND CURRICULUM PROPOSAL

To: Dr. Dennis Livesay, Chair of The Graduate Council

From: Department of Mathematics and Statistics

Date: October 09, 2015

Re: Establishment of New Course MATH 7180/8180

Please find the attached proposal to establish one new math course MATH 7180/8180 – Advanced Numerical Methods in Scientific Computing.

MATH 10-09-15

University of North Carolina at Charlotte

New Graduate

Course and Curriculum Proposal from: Department of Mathematics and Statistics

Title: Establishment of New Course MATH 7180/8180

II. CONTENT OF PROPOSAL

A. PROPOSAL SUMMARY

1. PROPOSAL SUMMARY

The Department of Mathematics and Statistics proposes to create a new graduate-level mathematics course MATH 7180/8180 – Advanced Numerical Methods in Scientific Computing. This elective course is intended primarily for MS and PhD students in Applied Mathematics.

B. JUSTIFICATION

1. Identify the need addressed by the proposal and explain how the proposed action meets the need.

With the rapid development of computer technology in recent decades, scientific computing has become an indispensable part of almost all scientific investigation and technological development at universities, government laboratories, and within the private sector. From a computational mathematician's point of view, central to scientific computing are numerical methods for solving various mathematical problems. In the past 20-30 years, many advanced numerical methods have been developed, and applications of these methods have spanned wide including modeling and analysis of problems in biology, electromagnetics, nano-optics, material science, semiconductor devices to name a few. None of the existing Numerical Analysis courses offered by the department, however, covers these advanced numerical methods.

The proposed MATH 7180/8180 course "Advanced Numerical Methods in Scientific Computing" is a survey of state-of-the-art numerical methods in scientific computing for applications particularly in biology, nano-optics, electromagnetic wave scattering, electron transport in plasma and semi-conductors. By offering this course, we aim to expose our graduate students in Applied or Computational Mathematics to the highest level of development of numerical algorithms and prepare them for future industrial and academic careers in scientific computing.

2. **Discuss prerequisites/corequisites for course(s) including class-standing, admission to the major, GPA, or other factors that would affect a student's ability to register.**

   The prerequisites for this course are MATH 5172 and MATH 5176, or permission of the department. MATH 5172: The Finite Element Method and MATH 5176: Numerical Methods for Partial Differential Equations are two elective courses for MS and PhD students in Applied Mathematics.

3. **Demonstrate that course numbering is consistent with the level of academic advancement of students for whom it is intended.**

   The UNC Charlotte course numbering guidelines have been followed for the proposed new course number MATH 7180/8180 which positions the course as a graduate course for MS and PhD students in the Mathematics and Statistics department.

4. **In general, how will this proposal improve the scope, quality and/or efficiency of programs and/or instruction?**

   This course will introduce students state-of-the-art numerical methods in scientific computing for applications in biology, nano-optics, electromagnetic wave scattering, electron transport in plasma and semi-conductors, etc. As such, this course will be a useful elective course for students in the Applied Mathematics MS and PhD programs. It may also be a potential useful elective course for graduate students in programs of other STEM disciplines.

5. **If course(s) has been offered previously under special topics numbers, give details of experience including number of times taught and enrollment figures.**

   Topics in the proposed course have been previously taught in a special topics graduate course for several times and the course enrollments varied from 3 to 6. In addition, most topics in the proposed course have also been previously taught in MATH 7176/8176 – Advanced Numerical Analysis in Fall 2014, and the course enrollment was 5.

C. **IMPACT.**

1. **What group(s) of students will be served by this proposal? (Undergraduate and/or graduate; majors and/or non-majors, others? Explain). Describe how you determine which students will be served.**

   This elective course will primarily serve MS and PhD students in Applied Mathematics. Graduate students from other STEM departments may also find it useful and choose to take it as an elective, but in this case they must have solid mathematical background in such areas as differential equations, finite difference and finite element methods, etc.

2. What effect will this proposal have on existing courses and curricula?

a. When and how often will added course(s) be taught?

This elective course will be taught on demand, but we expect that there will be sufficient demand for it to be offered once every other year.

b. How will the content and/or frequency of offering of other courses be affected?

The course covers state-of-the-art numerical methods in scientific computing, most of which were developed within the past 20-30 years. As such, its content doesn't overlap with other courses offered by the department. Also, to the best of our knowledge, the course doesn't overlap with courses offered by outside departments either. So the content of other courses on the campus will not be affected. On the other hand, since the initial motivation of adding this course was to replace an existing course MATH 7176/8176: Advanced Numerical Analysis which covers some conventional topics beyond finite difference and finite element methods, we do expect the frequency of offering of MATH 7176/8176 will be affected significantly. More specifically, we intend to change the frequency of offering of MATH 7176/8176 from "*Spring, odd years*" to "*On demand*" in our graduate course rotation schedule.

c. What is the anticipated enrollment in course(s) added (for credit and auditors)?

Due to the fact that the proposed MATH 7180/8180 course is a very advanced course in Numerical Analysis, we don't expect it will have a large enrollment. Rather its enrollment is anticipated to be around 5-8 students per offering, with 4-6 coming from the Mathematics and Statistics Department, and 1-2 coming from outside departments.

d. How will enrollment in other courses be affected? How did you determine this?

For the same reason as described in **b** above, we expect no impact of the MATH 7180/8180 course on the enrollment of other courses except for MATH 7176/8176. On the other hand, this new course may cause a lower enrollment of MATH 7176/8176, but it is our intention not to offer MATH 7176/8176 at least in next many years since the topics covered in this conventional Advanced Numerical Analysis course are no longer aligned with research areas of our faculty.

e. Identify other areas of catalog copy that would be affected, including within other departments and colleges (e.g., curriculum outlines, requirements for the degree, prerequisites, articulation agreements, etc.)

The course is to be used as an elective course for MS and PhD students in Applied Mathematics so it should be added as elective options in our graduate catalog. The specific changes needed in our graduate catalog can be found in **Attachment IV**. Other areas of the graduate catalog will not be affected.

III. Resources Required to Support Proposal.

A. Personnel

No new faculty is required to teach this course since Prof. Wei Cai from Mathematics and Statistics Department has taught most topics of the course in special topics and MATH 7176/8176 classes. He has developed and is interested in teaching this new course.

B. Physical Facility.

No additional facilities required.

C. Equipment and Supplies:

No additional equipment and supplies required.

D. Computer.

No additional computer resources required.

E. Audio-Visual.

No additional audio and visual resources required.

F. Other Resources.

Not applicable

G. Source of Funding

Not applicable

IV. Consultation with the Library and Other Departments or Units

A. Library Consultation.

The Dept. of Mathematics and Statistics consulted with Alison Bradley at the J. Murrey Atkins Library and was ensured that the present library holdings are adequate to support the proposed course. A copy of Consultation on Library Holdings can be found in **Attachment I**.

B. Consultation with other departments or units

The proposed course will have primary impact only within the Dept. of Mathematics and Statistics, although students from other departments may find it very useful and choose to take it as an elective. In addition, its content doesn't overlap with courses offered by other departments. As such, no consultation with other departments or units is conducted.

C. Honors Council Consultation

The proposal does not involve Honors programs as well as any Honors courses. As such, no consultation with the Honors Council is conducted.

V. Initiation, Attachments and Consideration of the Proposal

A. Originating Unit

Discussion regarding the creation of the new course initiated between Dr. Wei Cai, Dr. Yuanan Diao, Chair of the Mathematics and Statistics Department, and Dr. Shaozhong Deng, Graduate Coordinator of the Mathematics and Statistics Department.

Dr. Wei Cai developed the proposed course. By October 8, 2015, the department Graduate Curriculum Committee, including Drs. Shaozhong Deng (Chair), Joel Avrin, Wei Cai, Victor Cifarelli, Anthony Fernandes, Jiancheng Jiang, Shaoyu Li, and Weihua Zhou, has approved the proposed course by a 8-0 vote. A copy of the committee's supporting letter can be found in **Attachment II**.

B. Credit Hour (Mandatory if new and/or revised course in proposal)

☒ The appropriate faculty committee has reviewed the course outline/syllabus for the course and has determined that the assignments are sufficient to meet the University definition of a credit hour.

C. Attachments

1. Consultation

   A copy of Consultation on Library Holdings can be found in **Attachment I**.

2. Course Outline/Syllabus

   Course outline/syllabus for the proposed course can be found in **Attachment III.**

3. Proposed Catalog Copy

   The proposed catalog copy for MATH 7180 can be found in **Attachment III.**

   a. For MATH 7180, check all the statements that apply:

   __X_ This course will be cross listed with another course. (namely, MATH 8180)

   __X_ There are prerequisites for this course.

   ____ There are corequisites for this course.

   ____ This course is repeatable for credit.

   ____ This course will increase/decrease the number of credits hours currently offered by its program.

   ____ This proposal results in the deletion of an existing course(s) from the degree program and/or catalog.

4. ACADEMIC PLAN OF STUDY (UNDERGRADUATE ONLY)

   ☐ Yes.
   ☐ No.

5. STUDENT LEARNING OUTCOMES (UNDERGRADUATE & GRADUATE)

   ☐ Yes.
   ☒ No.

6. TEXTBOOK COSTS

   ☒ Yes. Briefly explain below.
   ☐ No. Briefly explain below.

The university's library has purchased full access to the electronic version of the main textbook "Computational Methods for Electromagnetic Phenomena: Electrostatics in solvation, scattering, and electron transport, Wei Cai, Cambridge University Press, 2013" so students don't need to buy a printed copy of the textbook.

Attachment I: Consultation on Library Holdings

UNC CHARLOTTE

J. Murrey Atkins Library

Consultation on Library Holdings

To: Shaozhong Deng

From: Alison Bradley

Date: 10/6/15

Subject: MATH 7180--Advanced Numerical Methods in Scientific Computing

Summary of Librarian's Evaluation of Holdings:

Evaluator: Alison Bradley Date: 10/6/15

Check One:

1. Holdings are superior ____
2. Holdings are adequate __x__
3. Holdings are adequate only if Dept. purchases additional items. ____
4. Holdings are inadequate ____

Comments:
Library holdings should be adequate to support student research for this course (see list of items held by subject heading below). Students will have access to relevant databases including MathSciNet, SpringerLink, ScienceDirect, and many others.

LC Subject Heading	Books	Journals
Numerical analysis	1217	55
Numerical analysis Data processing	222	17
Mathematical physics	1661	81

Evaluator's Signature

10/6/15

Date

Attachment II: Letter from Graduate Curriculum Committee

UNC CHARLOTTE
College of Liberal Arts & Sciences
Mathematics and Statistics

9201 University City Blvd, Charlotte, NC 28223-0001
t/ 704.687.0620 f/ 704.687.1392 math@uncc.edu

TO: Yuanan Diao, Chair, Dept. of Mathematics and Statistics

FROM: Shaozhong Deng, Chair, Graduate Curriculum Committee. J. Deng
Dept. of Mathematics and Statistics

RE: Establishment of New Course MATH 7180/8180

DATE: October 8, 2015

The 2015-2016 Graduate Curriculum Committee has approved by a 8-0 vote the proposal of establishing the new graduate course MATH 7180/8180 – Advanced Numerical Methods in Scientific Computing.

Please feel free to contact me at 704-687-0634 or shaodeng@uncc.edu if you have any questions.

The UNIVERSITY *of* NORTH CAROLINA *at* CHARLOTTE

Attachment III:

Course Description and syllabus

MATH 7180/MATH 8180
Advanced Numerical Methods in Scientific Computing

Course Description (Proposed Catalog Copy):

MATH 7180. Advanced Numerical Methods in Scientific Computing (3). Prerequisites: MATH 5172 and MATH 5176, or permission of the department. This course introduces advanced numerical methods in scientific computing. Topics include Particle-Mesh Ewald and the Fast multipole methods, boundary element methods, absorbing and perfectly matched layered boundary conditions, Yee's finite difference and discontinuous Galerkin methods, surface integral equation methods, Nedelec edge elements for Maxwell equations, Bloch theory and periodic structures and photonics, Boltzmann and Wigner kinetic methods, high resolution Godunov methods and WENO methods for hydrodynamic equations, particle-in-cell and constrained transport methods for magnetohydrodynamics. (*On demand*)

MATH 8180. Advanced Numerical Methods in Scientific Computing (3). Prerequisites: MATH 5172 and MATH 5176, or permission of the department. This course introduces advanced numerical methods in scientific computing. Topics include Particle-Mesh Ewald and the Fast multipole methods, boundary element methods, absorbing and perfectly matched layered boundary conditions, Yee's finite difference and discontinuous Galerkin methods, surface integral equation methods, Nedelec edge elements for Maxwell equations, Bloch theory and periodic structures and photonics, Boltzmann and Wigner kinetic methods, high resolution Godunov methods and WENO methods for hydrodynamic equations, particle-in-cell and constrained transport methods for magnetohydrodynamics. (*On demand*)

Course Objectives:

The overall objective of this course is to introduce state-of-the-art numerical methods in computational physics for applications in biology, nano-optics, electromagnetic wave scattering, electron transport in plasma and semi-conductors. Upon completion of this course, for each numerical method introduced, students are expected to be able to understand the underlying physical application, the key concepts, ideas, and techniques used in the development of the method, as well as the advantage and disadvantage of the method. Through this course the students are also expected to gain a broad knowledge in several disciplines including applied mathematics, electromagnetics, physics, and optical science. In addition, the students are expected to develop some (or strengthen their) programming skills using at least one common programing language such as Matlab and become somewhat well-rounded in both numerical algorithm development and their eventual implementation.

Instructional Method:

The primary format for instruction will be lectures. There will be a total of forty-five 50-minute lectures.

Means of Student Evaluation:

Student performance will be evaluated by class attendance, homework assignments, and computing projects. (The weight of these components will be at the discretion of the course instructor.) It is anticipated that final letter grades will be awarded as follows:

A = 90% to 100%, B = 80% to 89%, C = 70% to 79%, U = <70%

Class Policies:

Late homework/computer project policy: Homework/computer project is due at the beginning of class on the due date. No late homework/computer project will be accepted without legitimate reasons.

Attendance policy: Students are expected to be present and ON TIME for ALL class sessions. If a student misses more than 5 classes, the student will receive a U for the final grade without exception.

Classroom Policies: http://legal.uncc.edu/legal-topics/classroom-policies-and-practices

Academic Integrity: http://legal.uncc.edu/policies/up-407

Textbook and Reference:

Wei Cai, Computational Methods for Electromagnetic Phenomena: Electrostatics in solvation, scattering, and electron transport, Cambridge University Press, 2013.

Charles Hirsh, Numerical Computation of Internal and External Flows, Vol. II, Chapter 16 (for lectures 41-42)

Topical Outline of Course Content:

- *Section numbers refer to Cai, Computational methods for Electromagnetic Phenomena, Cambridge University Press, 2013*

- **Lectures 1-3, Polarization and dielectric constant** (Sections 1.1, 1.2, 1.3.1, 1.5.1)

  1.1 Electrostatics of charges and dipoles

  1.2 Polarization **P** and displacement flux **D**

  1.3.1 Clausius–Mossotti formula for non-polar dielectrics

- **Lectures 4-5, Many body interaction–periodic systems** (Sections 4.1, 4.2)

  4.1 Ewald sums for charges and dipoles

  4.2 Particle-mesh Ewald (PME) methods 2

- **Lectures 5-7, Many body interaction – non-periodic system** (Section 4.3)

  4.3 Fast multipole methods for *N*-particle electrostatic interactions

- **Lectures 8-10, Poisson-Boltzmann (PB) theory in electrolytes** (Sections 2.1.1, 2.3.1, 2.3.2, 2.3.4)
  2.1.1 Debye–Huckel Poisson–Boltzmann theory
  2.3.1 Methods of images for simple geometries
  2.3.2 Image methods for dielectric spheres
  2.3.4 Image methods for multi-layered media

- **Lectures 11-12, Integral equation method for PB equations** (Sections 3.1.1, 3.1.2)
  3.1.1 Cauchy principal value (CPV) and Hadamard finite part
  3.1.2 Surface integral equations for the PB equations

- **Lecture 13, regularization of singular integrals and direct computation of CPV** (Section 3.1.3)
  3.1.3 Computations of CPV and Hadamard p.f. and collocation BEMs

- **Lecture 14, Finite element method for PB equations** (Section 3.2)
  3.2 Finite element methods (FEMs) & Multi-grid method

- **Lectures 15-17, Boundary and interface conditions for EM field** (Sections 5.1.1, 5.3.1, 5.3.2)
  5.3.1 Interface conditions between dielectric media
  5.3.2 Leontovich impedance boundary conditions for conductors

- **Lectures 18-19, ABC for EM field** (Section 5.4)
  5.4 Absorbing boundary conditions for **E** and **H**

- **Lectures 20-21, Dyadic Green's functions in layered media** (Sections 6.1, 6.2.1-6.2.3)
  6.1 Singular charge and current sources
  6.2.1 Dyadic Green's functions for homogeneous media
  6.2.2 Dyadic Green's functions for layered media
  6.2.3 Hankel transform for radially symmetric functions

- **Lecture 22, Potentials for Green's functions** (Sections 6.2.5, 6.3.1)
  6.2.5 Longitudinal components of Green's functions
  6.3.1 Sommerfeld potentials 3

- **Lecture 23, Huygens's principle and integral equations** (Section 7.1.1)
  7.1.1 Integral representations of electromagnetic fields

- **Lecture 24, Singular Integral Equation (IE)** (Section 7.1.2)
  7.1.2 Singular and hyper-singular surface integral equations

- **Lectures 25-26, Method of Moments for Surface IE method** (Sections 7.4.1-7.4.3)
  7.4.1 Galerkin method using vector–scalar potentials
  7.4.2 Functional space for surface current **J(r)**
  7.4.3 Basis functions over triangular–triangular patches

- **Lectures 27-28, Edge finite element methods for Maxwell equations** (Sections 8.1/8.1.1)
  8.1.1 Finite element method for E or H wave equations
  8.1.3 Nedelec finite element basis in H(curl)

- **Lectures 29-31, Scattering in periodic structures** (Sections 10.1.1-10.1.3, 10.1.5)
  10.1.1 Bloch theory for 1-D periodic Helmholtz equations
  10.1.2 Bloch wave expansions
  10.1.3 Band gaps of photonic structures
  10.1.5 Rayleigh–Bloch waves and band gaps by transmission spectra

- **Lecture 32-33, Eigen-mode computations for periodic structures** (Sections 10.2.1, 10.2.2)
  10.2.1 Nedelec edge element for eigen-mode problems.
  10.2.2 Time-domain finite element methods for periodic array antennas

- **Lecture 34-35, Time domain Discontinuous Galerkin methods for Maxwell equation** (Sections 9.1-9.3)
  9.1 Weak formulation of Maxwell equations
  9.2 Discontinuous Galerkin (DG) discretization
  9.3 Numerical flux h(u−, u+)

- **Lecture 36, Time domain Yee finite difference Schemes** (Sections 9.7, 16.4)
  9.7 Finite difference Yee scheme
  16.4 $\nabla \cdot B = 0$ constrained transport methods for MHD equations 4

- **Lectures 37-40, Boltzmann and Wigner kinetic theory** (Section 12.3,16.1,16.3)
  12.3 Wigner-Moyal expansion (12.114) and hydrodynamic equations (15.17)
  16.1 Vlasov-Laudau-Fokker-Planck equations for plasma system

16.3 Particle-in-Cell scheme for plasma

- **Lectures 41-42, Riemann problem for scalar conservation laws,** (Hirsh, Section 16.6) Burger equation, characteristics, Rankine-Hogoniot condition, etc

- **Lectures 43-45, Godunov type methods for hydrodynamic and MHD transport** (Section 15.2, 15.3, 16.4)
  - 15.2 High-resolution finite difference methods of Godunov type
  - 15.3 Weighted essentially non-oscillatory (WENO) finite difference methods
  - 16.4 Constrained transport methods for MHD of plasma.

Attachment IV: Changes needed in the catalog

Changes are needed at only three places in the catalog.

Concentration In General Mathematics

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Group I Applied Mathematics

- OPRS 5111 - Linear Programming (3)
- OPRS 5112 - Nonlinear Programming (3)
- OPRS 5113 - Game Theory (3)
- OPRS 5114 - Dynamic Programming (3)
- MATH 5165 - Numerical Linear Algebra (3)
- MATH 5172 - The Finite Element Method (3)
- MATH 5173 - Ordinary Differential Equations (3)
- MATH 5174 - Partial Differential Equations (3)
- MATH 5176 - Numerical Methods for Partial Differential Equations (3)
- MATH 7172 - Partial Differential Equations (3)
- MATH 7176 - Advanced Numerical Analysis (3)
- MATH 7177 - Applied Optimal Control (3)
- MATH 7178 - Computational Methods for Fluid Dynamics (3)
- MATH 7180 - Advanced Numerical Methods in Scientific Computing (3)
- MATH 7273 - Advanced Finite Element Analysis (3)

Concentration in Applied Mathematics

The Master of Science degree concentration in Applied Mathematics is designed to develop critical thinking, intuition, and advanced experience in the techniques of mathematical analysis and their application to the problems of industry and technology. Skills are developed to deal with technical problems encountered in industry, business, and government and to hold leadership positions therein; to teach Applied Mathematics at the undergraduate or community college level; and to potentially study Applied Mathematics leading to the Ph.D. degree.

Concentration Requirements

A candidate for the Master of Science degree concentration in Applied Mathematics must complete at least 30 credit hours of graduate work approved by the department Graduate Committee to include:

Core Courses (21 credit hours)

- MATH 5143 - Analysis I (3)
- MATH 5144 - Analysis II (3)
- MATH 5165 - Numerical Linear Algebra (3)

Numerical Analysis Courses

Select one of the following:

- MATH 5172 - The Finite Element Method (3)
- MATH 5176 - Numerical Methods for Partial Differential Equations (3)

Advanced Analysis Courses

Select one of the following:

- MATH 7141 - Complex Analysis I (3)
- MATH 7143 - Real Analysis I (3)
- MATH 7144 - Real Analysis II (3)

Advanced Applied Mathematics Courses

Select two of the following:

- MATH 7172 - Partial Differential Equations (3)
- MATH 7176 - Advanced Numerical Analysis (3)
- MATH 7177 - Applied Optimal Control (3)
- MATH 7178 - Computational Methods for Fluid Dynamics (3)
- MATH 7180 - Advanced Numerical Methods in Scientific Computing (3)
- MATH 7273 - Advanced Finite Element Analysis (3)

Elective Courses (6 credit hours)

Advanced Elective Courses

Select one of the following:

- MATH 7141 - Complex Analysis I (3)
- MATH 7143 - Real Analysis I (3)
- MATH 7144 - Real Analysis II (3)
- MATH 7172 - Partial Differential Equations (3)
- MATH 7176 - Advanced Numerical Analysis (3)
- MATH 7177 - Applied Optimal Control (3)
- MATH 7178 - Computational Methods for Fluid Dynamics (3)
- MATH 7180 - Advanced Numerical Methods in Scientific Computing (3)
- MATH 7273 - Advanced Finite Element Analysis (3)
- MATH 7893 - Thesis (0-3)

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